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Spaceflight

The International Magazine of Space and Astronautics

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 30 No. 1 January 1988

Front Cover: A model of the Energia launch vehicle on display at the SPACE '87 Exhibition, Brighton, organised by the British Interplanetary Society and attended by school parties and teachers on its final day of opening. New information on the Energia rocket and Mir Complex revealed at this Exhibition is presented by Peter Bond on p.15.
P. J. Fulford

Debris Hazard Poses Future

by Ralph D. Lorenz

In the early days of space exploration, one of the great fears was that spacecraft would be destroyed by collision with meteoroids. This fear proved to be largely unfounded, the natural meteoroid flux being less than was thought. However, the possibility is growing that spacecraft around the Earth may be damaged by the increasing amount of artificial space debris.

Space debris can be effectively put into three classes: particles, fragments and artifacts, the broad characteristics of which are shown in Table 1. It can be produced in a number of ways, some of which are common to more than one class of debris.

Many tiny particles of aluminium oxide are produced by solid rocket motors used in space – although most rockets burn 'cleanly' with a gaseous exhaust, solids using aluminium to increase their energy tend to generate billions of Al_2O_3 particles in the 1-10 μm range.

Larger particles include paint flakes; spacecraft are normally coated with thermal paint to help control their temperature, but with the intense thermal cycling in the space environment this paint can easily flake off.

Many particles are produced by explosions, both accidental and deliberate and natural meteoroids could be included in the particle category. However, whereas meteoroids are normally 'passing through' near-Earth space with a typical velocity of 20 km/s, particles of debris are in fixed orbits and their velocity with respect to a spacecraft will depend on the difference between the two objects' inclinations (the relative velocity is usually taken to be about 10km/s). Also, natural meteoroids have a density of around 0.5 g/cm^3, while artificial debris is denser, about 2.5 g/cm^3. The relative numbers of meteoroids and artificial debris are shown in Fig. 1.

Numerous parts of spacecraft are jettisonned during launch and operation and these come under the fragment category. Fragments of this type include interstage structures, payload shrouds and support structures (e.g. SYLDA on Ariane). The production of

Columbia's Close Encounter

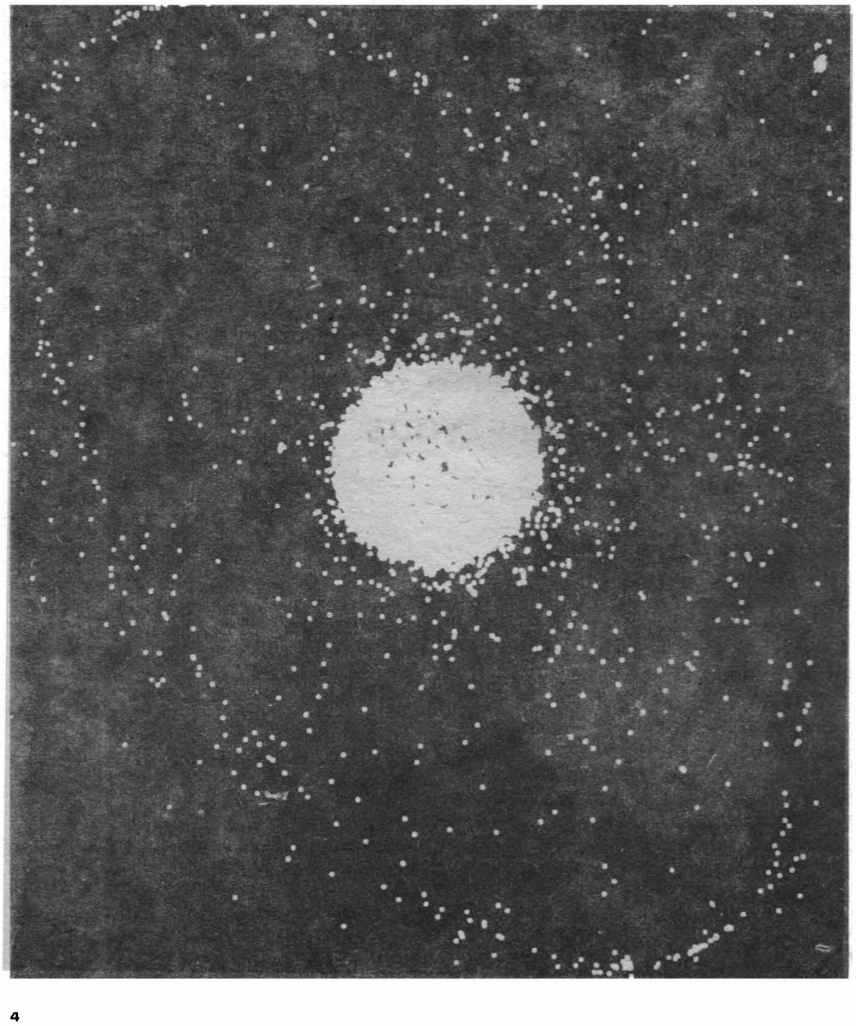
On July 2 1982, on the fifth day of its final test flight, the US space shuttle Columbia flew uncomfortably close to the burned-out upper stage of a 1975 Soviet Intercosmos rocket.

Flying above the north-western coast of Australia, Ken Mattingly and Henry Hartsfield passed within eight miles of the stage. It flew past them at almost 7,000 mph (11,200 kph) above and in front of the Orbiter.

Mission Control said that there was no danger of collision and that Columbia could have taken evasive action if necessary. The Flight Director commented: "No way could they have seen that thing. You'd have to be looking at exactly the right place at exactly the right time and not blink."

Spaceflight, Jan 1983

A computer prepared distribution of debris from space launches in the vicinity of the Earth NORAD and NASA's Goddard Space Flight Centre recently estimated from radar data a total of 6194 objects of baseball size or greater, of which 1582 were payloads, 68 interplanetary probes, 4488 were pieces of debris in satellite orbit and 56 were pieces of debris in interplanetary orbit Those objects which are in or close to geostationary orbit now form a clearly defined ring



Spotlight

Problems posed by space debris were highlighted at the 38th IAF Congress held in Brighton last October when leading space experts analysed the growth of Earth orbital fragments before a gathering of international delegates.

While the known population of Earth satellites is increasing at a rate of more than 300 satellites per year, the growth of small satellite fragments may be substantially greater due to either deliberate or unintentional satellite fragmentations.

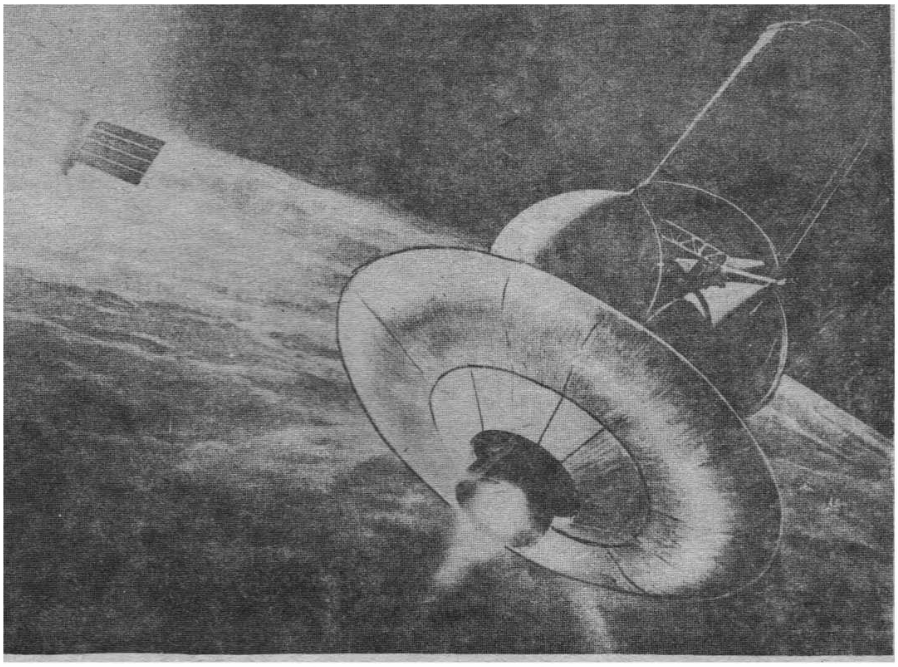
According to Nicholas L. Johnson of Teledyne Brown Engineering the most densely populated altitude region in 1977 was 800-850 km, having 1.49 x 10^{-8} satellites/km^3, whereas by 1987 this value had increased by 41 per cent. For the 950-1000 km region, which is now penetrated by one-third of all known satellites, the increase was 128 per cent making this the region of greatest spatial density. The primary cause of these increases was the break-up of Cosmos 1275 on July 24 1981 into over 200 trackable fragments at 977 km altitude.

Threat

fragments on separation is so well-established that characteristic patterns of fragments can be used to identify launch vehicles: a four-fragment 'fingerprint' identifies an unannounced Soviet SL-16 Medium Lift Booster.

A principal source of fragments and particles is the destruction of space vehicles. Residual propellant left in upper stages can explode, sometimes after many months or even years in orbit. Several Delta upper stages have exploded in space and in November 1986 an Ariane third stage exploded throwing debris from the stage's 790 km orbit to altitudes from 430 km to 1350 km. The explosion (probably resulting from the corrosion of the wall separating the fuel and oxidiser in the tank) produced 200 pieces of trackable debris (i.e. with a diameter greater than 1 cm) and probably thousands of smaller particles.

Spacecraft may be destroyed in orbit deliberately for a number of reasons: anti-satellite weapons system testing has resulted in the destruction of many spacecraft e.g. Solwind, Cosmos 249, 374, 375 etc. Such testing usually involves the detonation of on-board explosives or high velocity collision – in September 1986 a 'Star Wars' test involved the high velocity collision of two rocket stages, resulting in the complete disintegration of both.



A future orbital transfer vehicle (OTV) capable of operation in geosynchronous orbit could perform a similar role as an OMV (orbital manoeuvring vehicle) in lower orbits in helping clear larger items of space debris or moving exhausted satellites. *Martin Marietta*

The debris from collisions and explosions tends to spread out into a cloud and eventually into a 'torus' surrounding the Earth. Spacecraft may also be commanded to self-destruct in order to prevent their impact on populated areas of the Earth's surface, or, with military spacecraft, to prevent recovery by foreign intelligence agencies.

Another potential source of debris is the break-up of the nuclear power supplies of some satellites, notably Soviet ocean reconnaissance craft. When these craft reach the end of their useful life, the nuclear power pack is boosted into a higher orbit to prevent its falling back to Earth while it is still dangerously radioactive. Large numbers of fragments, including pellets of nuclear fuel, could subsequently be

On Orbital Pollution

An important question is whether the fragmentation of Cosmos 1275 in 1981 was the result of a hypervelocity collison or not.

The expanded use of geosynchronous and deep space orbits has also measurably increased the probabilities of collision at higher altitudes. Since 1977 the spatial density at geosynchronous altitudes has increased by more than two orders of magnitude, from 1.85×10^{-11} to 2.38×10^{9} satellites/km^3, although this region still remains less hazardous than the low orbiting altitudes.

An important question before delegates was whether or not the fragmentation of Cosmos 1275 was the result of a hypervelocity collision with an untracked object. If it was, a vast number of unseen, small satellite fragments would have resulted, easily raising the above spatial densities and collision probabilities by several orders of magnitude.

"The need to identify the cause of each satellite fragmentation is essential to future orbital debris analysis," said Darren S. McKnight of the USAF Academy, adding: "Over 70 per cent of all satellite break-ups of unknown cause are of Soviet origin while about 30 per cent are of US origin. Therefore we must begin open discourse in these matters in order to identify the cause of these break-ups and thus mitigate the space debris hazard to all satellites in the future."

A more recent case of fragmentation, the cause of which is still under investigation, is that of the Spot/Viking rocket body on November 13, 1986, which gave rise to almost 500 detectable pieces, the vast majority of which were thrown into very long-lived orbits. Some of these pieces already traverse the altitudes frequented by manned spacecraft and the rest will eventually decay through this region.

The increasing congestion of the geostationary orbit was highlighted by Dr. G.C.M. Reijnen of the Faculty of Law, Utrecht University, who foresaw the need to update the existing technical regulations of the International Telecommunications Union (ITU) and the existing basic regulations of space law.

Although the current international legal requirements contain general principles that are relevant to orbital debris, especially the Outer Space Treaty, David Reibel of the Institute for Security and Cooperation in Outer Space considered them to be inadequate.

The current international legal requirements contain general principles relevant to orbital debris but are inadequate.

He pointed out that domestic laws had a role in the prevention of orbital debris since Article VI of the Outer Space Treaty established that "States Parties of the Treaty shall bear international responsibility for national activities in outer space".

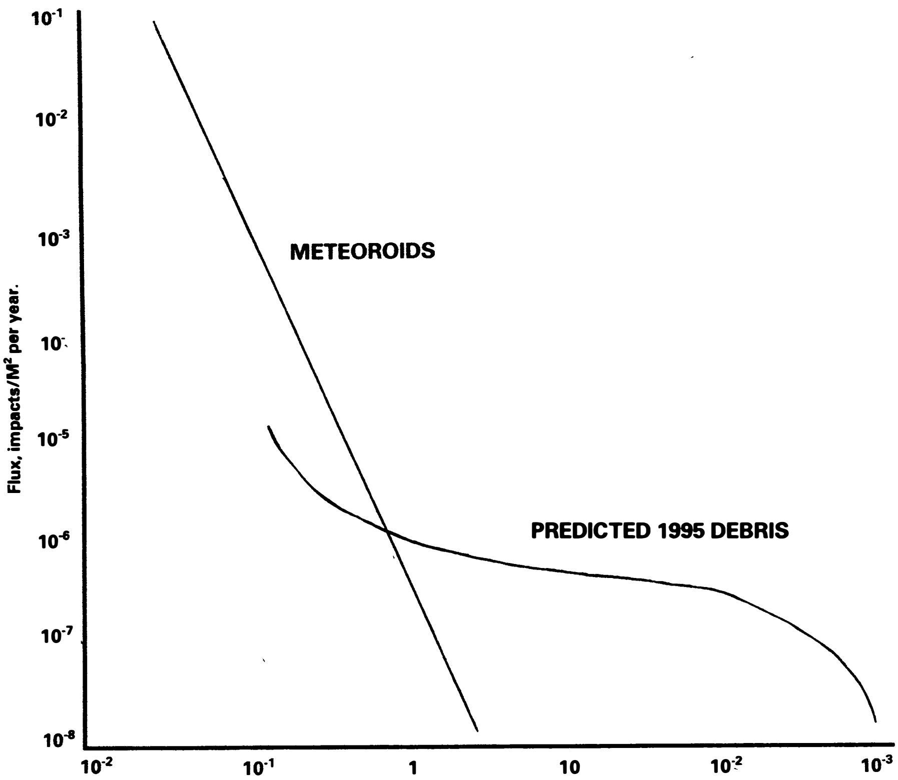


Fig. 1 Predicted debris/meteoroid population for typical 400 km orbit.

released as a result of the disintegration of the unit, perhaps owing to a debris impact.

The term artifacts is applied to whole items of space hardware, such as intact payload support structures, used upper stages, and spacecraft. Spacecraft can become derelict in a number of ways: following the malfunction of a launch vehicle or upper stage; insertion into incorrect, useless orbits; a malfunction as a result of internal component failure, loss of power, or damage caused by collision or radiation. Termination of a spacecraft's mission is frequently necessitated by the exhaustion of attitude control/station keeping propellant.

NORAD currently tracks something in excess of 6200 objects in orbit, consisting of objects with dimensions of a few centimetres or more that are visible in radar. Of this number, only 5 per cent are operating satellites. In addition to these comparatively large objects, there are many more smaller fragments – estimates of "marble-sized" pieces are normally around a dozen times the number of trackable objects.

An indication of the probability of collision with various sizes of debris particles for low-Earth orbits is given in Fig. 1. Radar observations and computer models indicate that the worse place to be is in an 800 km orbit with an inclination of about 120 degrees. In general, orbits from about 500 km to 1100 km are regarded as being fairly hazardous.

As well as this area, the valuable (and hence crowded) geostationary belt is also becoming dangerous. Together with about 150 operating craft, there are dozens of defunct spacecraft and rocket motors. It is estimated that there are 600 trackable objects (greater than 1 m) and around 2,000 smaller pieces. When a spacecraft in geostationary orbit runs out of propellant, it can drift (the non-uniformity of the Earth causes an east-west drift, and the gravitational pulls of the Sun and Moon cause a north-south drift), through the areas occupied by active satellites.) NORAD has for several years operated a scheme whereby satellite operators are informed if a "near-miss" is predicted, a procedure which has allowed evasive manoeuvres to be made.

A major concern is that collisions tend to produce many small fragments, which in turn increase the probability of further collisions. The creation of a self-propagating debris belt (especially in the region used by geostationary satellites) is becoming a real fear.

Although spacecraft design engineers now take into account the space debris hazard when considering the hazard due to meteoroids (especially when strategically important or manned spacecraft are concerned), the question of whether any spacecraft have actually been damaged by debris is difficult to answer with complete certainty. Several spacecraft are suspected of being hit by artificial space debris, and some of the more well-documented cases are described below.

The largest window of the Apollo command module from third Skylab mission was examined closely using microphotography. During the 84 days it spent in space it was peppered with micrometeoroids, leaving tiny craters on the outside of the glass. It is suspected that a few of the craters (which had a different structure to the rest) were caused by the impact of small aluminium oxide particles from solid rocket motors.

In June 1983, on shuttle flight STS-7, the windscreen of Challenger was chipped. The small (2.4 mm) crater meant subsequent replacement of the window to prevent future launch or re-entry loads causing potentially dangerous cracks.

In July 1983, cosmonauts on board Salyut 7 heard a loud crack and found a 4 mm crater on the outside pane of one of their windows.

Although no-one can be completely certain whether either impact was caused by artificial debris or natural meteoroids, the Soviets attribute the cause to a meteoroid as a result of a meteor shower at the time. Alternatively, the Challenger impact has been attributed by some sources to a paint flake.

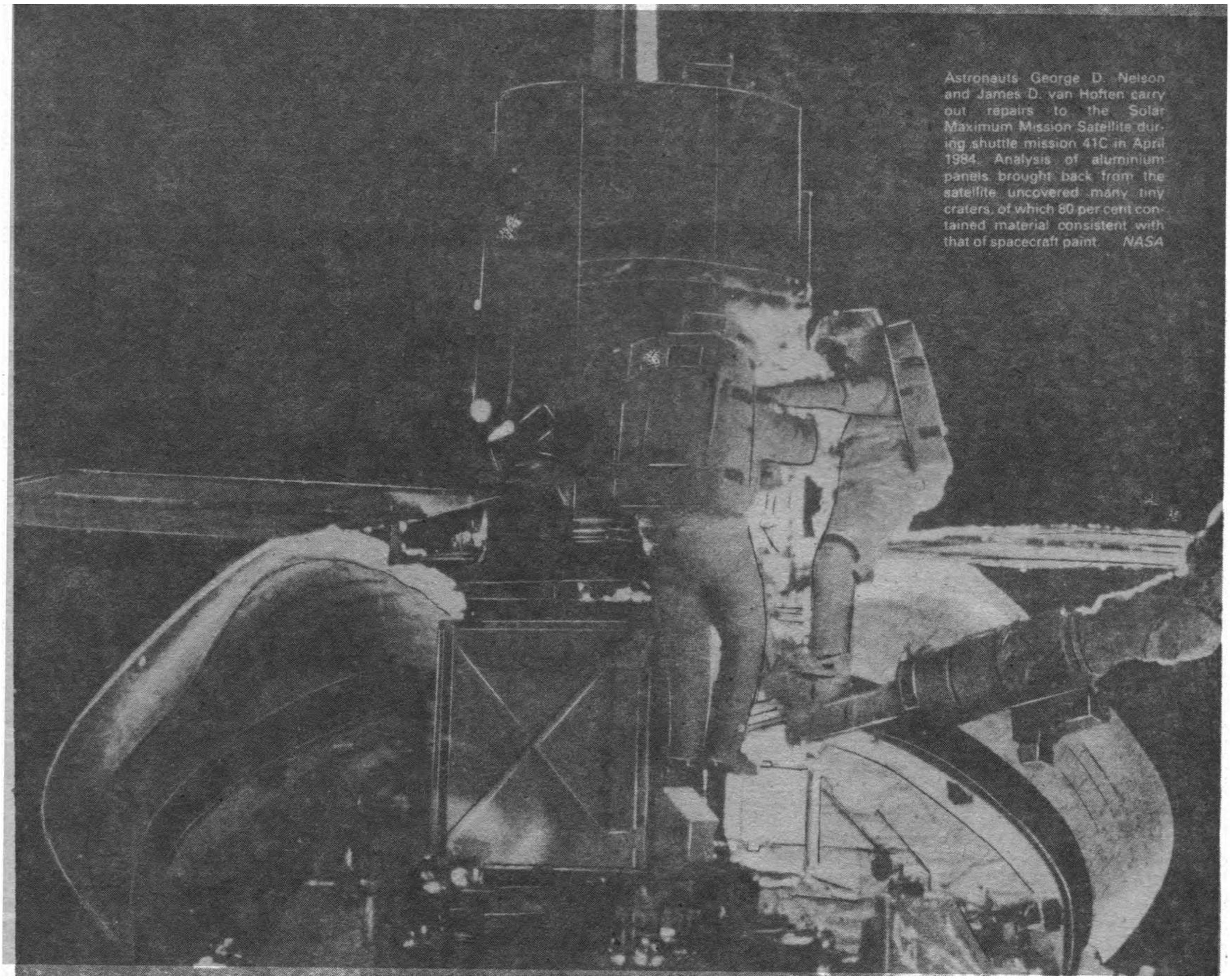
After shuttle astronauts on mission 41C repaired the Solar Maximum Mission satellite, they brought back aluminium panels from it. Analysis found that during four years in space the panels received impacts which created 331 tiny craters. Only 20 of these contained traces of meteoric material with some 266 containing material of a composition consistent with that of spacecraft paint.

Finally, an interesting case of two spacecraft accidentally colliding is that which occurred during the launch of the amateur satellite OSCAR-10. It was carried into orbit inside a SYLDA launch adaptor, on top of which was the communications satellite ECS-1. Once the combination had been injected into geostationary transfer orbit by its Ariane launch vehicle, ECS-

Table 1. Space debris characteristics.

Type	*Mass*	*Size /m*	*Composition*	*Radar Trackable*
Particle	<1g	<.01	very variable	no
Fragment	1g-100kg	.01-1	usually metallic	largerfragments only
Artifact	10-1000kg	>.1	mostly metallic	yes

Note Long axis order of magnitude only Very irregular structures (e g antenna) ignored



Astronauts George D. Nelson and James D. van Hoften carry out repairs to the Solar Maximum Mission Satellite during shuttle mission 41C in April 1984. Analysis of aluminium panels brought back from the satellite uncovered many tiny craters, of which 80 per cent contained material consistent with that of spacecraft paint. *NASA*

1 was released, followed by the upper half of SYLDA. Amsat-OSCAR-10 was then deployed successfully. However, a software error prevented a valve on Ariane's third stage (which was still attached to the lower half of SYLDA) from closing and the cold gas spewing out pushed Ariane so that it caught up with OSCAR-10 and collided with it. Several of OSCAR's antennae were bent, causing some degradation in the satellite's future performance, but the antennae absorbed most of the energy of the impact, thereby preventing more serious damage (to the solar arrays for example). Although ESA took measures to prevent such a collision occurring again, OSCAR-10's successor, P3C, has flexible antennae which are not as easily damaged.

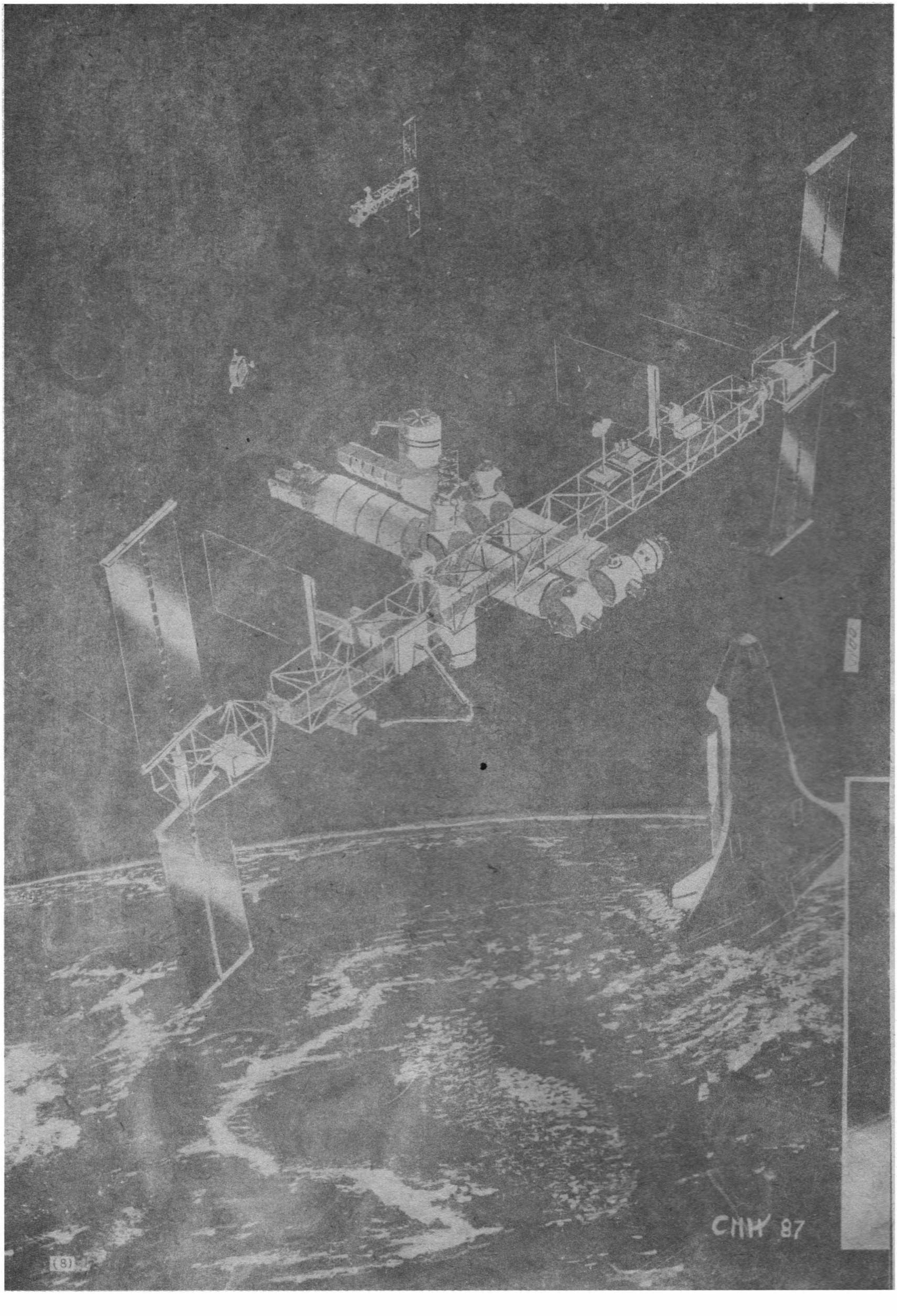
There are a number of ways of limiting the amount of "junk" that is put into orbit each year. Careful control of upper stage fairings can cause them to burn up safely in the Earth's atmosphere before they present a hazard to other craft in orbit. For upper stages with longer orbital lifetimes, any left over propellant is now vented to preclude the possibility of future explosion. Many, but by no means all, spacecraft are now taken 'out of the way' when their missions end. Many low-orbiting craft (many Soviet satellites and vehicles associated with their manned space programme) are de-orbited and burn up.

As for the geostationary belt, Intelsat has a policy of raising the orbits of its satellites by about 50 km when they reach the end of their lives. NOAA raises its craft by about 300 km, while ESA "de-synchronises" by 150 km or so. The Soviet Union does not raise the orbits of its geosynchronous craft completely, but gives them large eccentricities so that the amount of time they spend in the GEO belt is reduced. A number of satellite operators, however, do not move their craft, thereby jeopardising the safety of other GEO satellites.

It is estimated that there is a current probability of between 0.002 per cent and 0.003 per cent of two objects in geostationary orbit colliding per year. This will grow steadily.

Space station operations tend to generate a lot of rubbish which if simply dumped overboard on a regular basis would surround the station in a cloud of junk taking weeks or months to clear. The astronauts on the Skylab space station put their refuse into the large, empty liquid oxygen tank but a similar procedure would not be appropriate for a permanently-manned space station. The Russians, on the other hand, have an effective procedure whereby the Progress freighters which bring up supplies are filled with rubbish before undocking and de-orbiting. During periods when Progress craft were unavailable, however, the Russians have disposed of their waste through the airlock.

There are ways in which the rate of growth of the amount of orbiting space debris can be slowed, but the hazard will still continue to grow. Within 20 years or so, it will be necessary to ensure the safe use of space by clearing up at least some of the existing debris. A number of studies have been made into vehicles and devices for this purpose. The US space shuttle could act as a sort of Debris Collection Vehicle (DCV) is a very limited sense, but is not optimised for this application. More suitable would be the NASA/TRW Orbital Manoeuvering Vehicle (OMV) which will be able to reach some 2700 km above a space shuttle orbit. NASA is studying a device to be fitted to the OMV to enable it to capture tumbling or uncontrolled satellites and debris.


CMK 87

UK Plan for Space Rescue Capsule

People living on the planned international space station will need an emergency means of returning to Earth should an incident occur that necessitates abandoning pressurised habitation modules. Such a situation may arise, for example, as a result of impact damage.

NASA is currently examining alternative ways for rapidly evacuating its proposed space station, under circumstances which would preclude launch and preparation of a rescue space shuttle either on a time factor or because of the number of people to be returned.

One concept under consideration is that of the small rescue capsule, of which perhaps two or three capable of carrying up to six people, would be premanently attached to the space station for emergency use.

British Aerospace Space and Communications is keen to pursue work in this area following the announcement of its multi-role capsule concept during the SPACE '87 Exhibition (***Spaceflight*** December 1987, p. 400) at Brighton last October.

A number of roles, including an emergency escape system, that could be carried out by a ballistic or semi-ballistic capsule were identified by BAe and a study undertaken to explore whether these could be encompassed in a single system.

As well as an escape system such a multi-role capsule could also provide independent European manned access to orbit, manned space flight technology development, an unmanned micrograviity laboratory, contingency access to space station and service to polar platforms or man-tended free flyers.

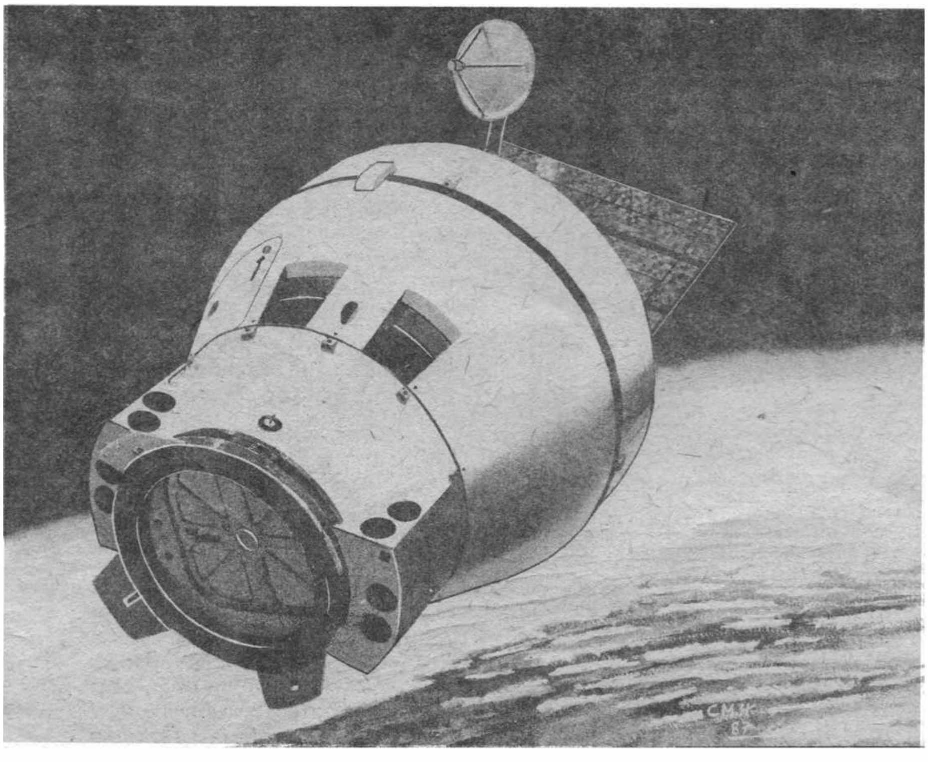
In a rescue mode the multi-role capsule would be capable of carrying six crew, albeit in rather cramped conditions. Measuring 4 m across and weighing about seven tonnes, its conical shape and an off-set centre of gravity would allow it to "fly" during re-entry, reducing acceleration forces on the crew and enabling more accurate landings.

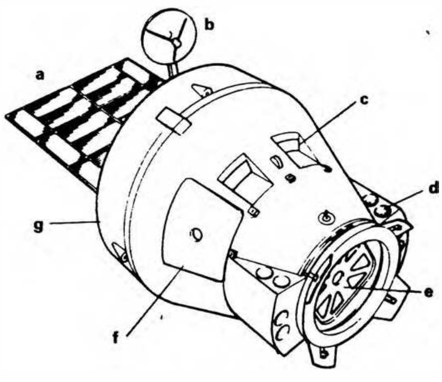
The capsule would use parachutes for braking and splash down in the ocean in the same way as the Mercury, Gemini and Apollo capsules.

Divided into two modules, the capsule, with a return weight of five tonnes, consists of a descent module and a service module. The latter is a cylindrical structure (discarded before re-entry) attached to the rear of the descent module. It houses a solar array for generation of electricity and various communications antennas.

The descent module is divided into three sections. The forward cabin with docking port, control thrusters, hygeine and galley facilities; the mid-cabin housing crew couches and control equipment; and the rear cabin containing batteries, propellant and air tanks, and a payload bay.

Left Artist's impression of space station in orbit with approaching shuttle and free-flying platform Note rescue capsules attached to habitation modules *Below* Capsule, showing docking interface, twin windows and access hatch *C.M Hempsell*





Main features of capsule: a solar array; b. data relay satellite link antenna; c. pilot and commander viewpoints; d. thruster pods; e. US/ISS compatible docking port; f. access hatch; g service/descent module separation.

The British Aerospace study identifies an Ariane 4 class rocket as a suitable launch system. A basic Ariane 4, the first of which is to be flown later this year, would require man-rating, primarily involving increased monitoring and additional redundancy for improved system safety. Launch would be by ground-only control with no facilities for crew intervention until after separation.

The launch system would need to provide some escape provisions in the event of a launch emergency. This would take the form of an escape rocket to pull the capsule away from the launcher. The rocket would be built into the upper fairing, which protects the docking port and thruster pods during the aerodynamic flight phase, and sized to carry the Descent Module to a height of two kilometres in the event of a "from the pad" abort. This type of system was used on the Apollo and on the Soyuz spacecraft The Soyuz system has been used successfully in actual emergency situations

Although Ariane's success rate to date is lower than that desirable for manned operations it should be noted that none of the failures have resulted in the immediate break up of the vehicle and escape could have been achieved by separation followed by a parachute descent

There would be an option to use Ariane 5 to launch a modified version of the Multirole Capsule with increased performance.

Other launchers were also briefly considered by the study, the most significant being the US space shuttle for delivery of Escape Capsules to the space station A shuttle launch would involve an alteration of the Service Module structure to interface with the payload bay trunnion mounting system. The front of the capsule would be supported by an airborne support structure which would also house the interface electronics.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

NASA Selects Space Station Contractors

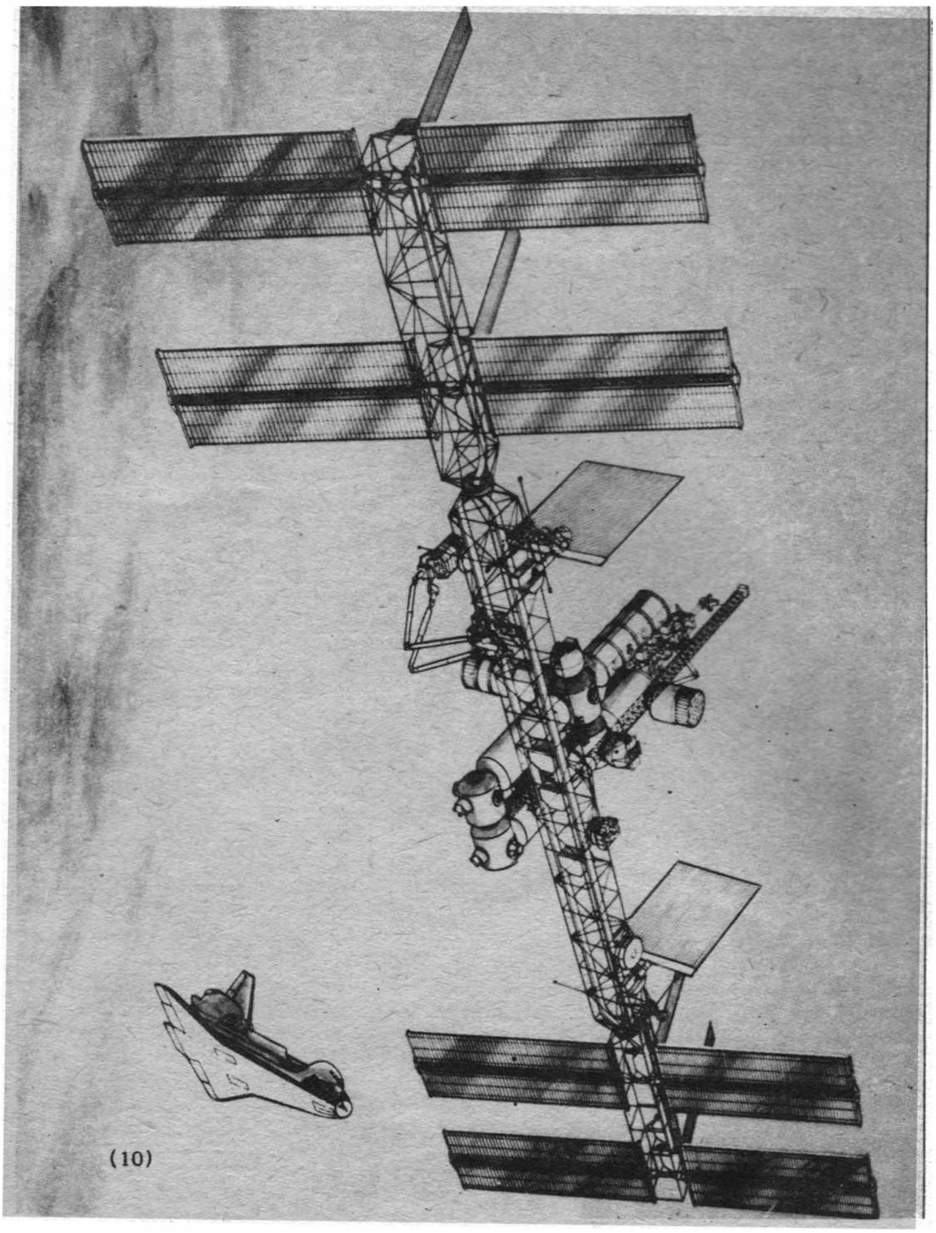
NASA has selected four aerospace firms for final negotiations leading to the award of contracts to design, develop, test, evaluate and deliver the components and systems comprising the permanently manned space station to be placed into Earth orbit in the mid-1990's.

The work is broken down into four packages each containing a unique but interdependent portion of the space station. Each is divided into two phases, with phase I covering currently approved elements and Phase II an option for possible future enhancement of the station's capabilities.

The four companies selected for the Phase I effort are: Boeing Aerospace, McDonnell Douglas Astronautics, General Electric (Astro-Space Division), and the Rocketdyne Division of Rockwell International.

Total cost proposed by the four companies is approximately $5 billion for the Phase I effort and $1.5 billion for Phase II.

Artist's concept of the manned space station in orbit. *McDonnell Douglas*



The companies selected offered technically superior proposals and proposed the lowest cost for their work package. The total cost is within NASA's estimate.

The contracts represent less than half of the estimated total space station cost of $14.6 billion and the programme is expected to generate some 12,000 jobs through out the US.

Approximately 300 people participated in each work package review and the contractors will work closely, under the direction of the Space Station Program Office, in designing, building and integrating the space station.

The contracts include two programme phases. Phase I will cover the approximate 10 year period from contract start to a year after assembly of the space station is completed. Phase II is a priced option which, if exercised, will enhance the capabilities of the station configuration by addition (in the 1991 to 1999 time frame) of an upper and lower truss structure, additional external payload attachment points, a solar dynamic power system, a free-flying coorbiting platform and a servicing facility.

Phase I of the Work Package 1 contract, managed by the Marshall Space Flight Center, calls for Boeing to provide the US laboratory and habitation modules, logistics elements, resource node structures, airlock systems, environmental control and life support system, internal thermal, audio and video systems and associated software.

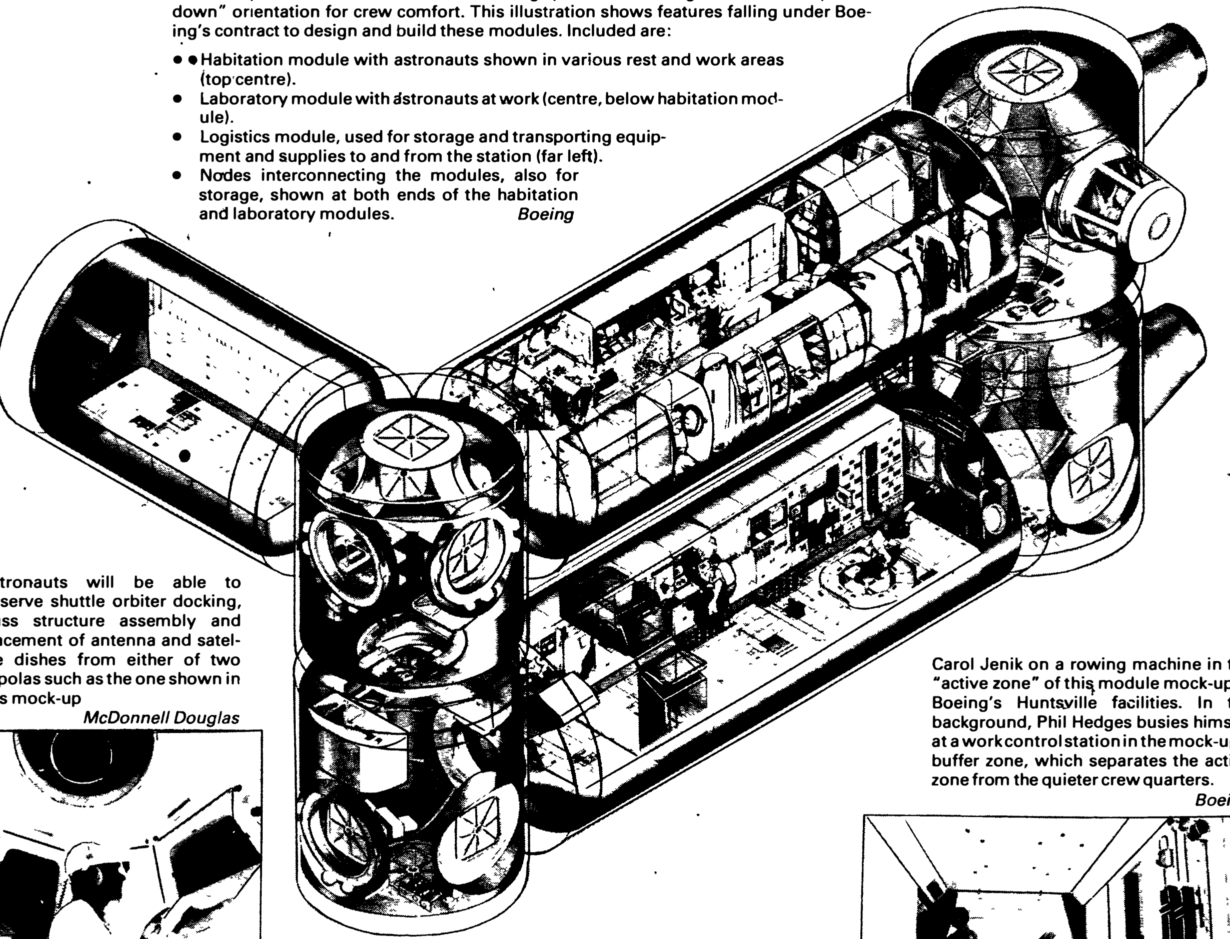
Overall management, systems engineering and integration, and operations and logistics support of these elements also will be performed by Boeing.

Major Boeing subcontractors are: Teledyne Brown Engineering, Lockheed, Hamilton Standard, Garrett Airesearch, Grumman Aerospace, ILC Space Systems, and Fairchild-Weston Systems.

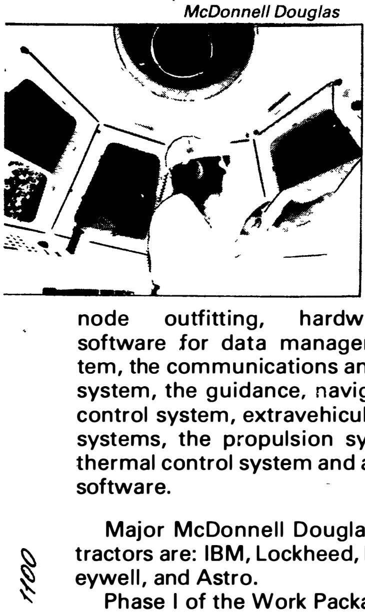
Phase I of the Work Package 2 contract, managed by Johnson Space Center, calls for McDonnell Douglas Astronautics to provide the integrated truss structure, mobile servicing system transporter, airlocks, resource

NASA's space station laboratories and living quarters are designed with an "up-and-down" orientation for crew comfort. This illustration shows features falling under Boeing's contract to design and build these modules. Included are:

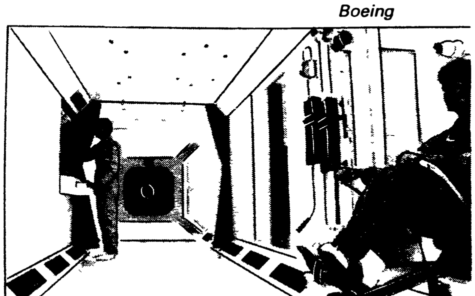
- Habitation module with astronauts shown in various rest and work areas (top centre).
- Laboratory module with astronauts at work (centre, below habitation module).
- Logistics module, used for storage and transporting equipment and supplies to and from the station (far left).
- Nodes interconnecting the modules, also for storage, shown at both ends of the habitation and laboratory modules. *Boeing*



Astronauts will be able to observe shuttle orbiter docking, truss structure assembly and placement of antenna and satellite dishes from either of two cupolas such as the one shown in this mock-up
McDonnell Douglas



Carol Jenik on a rowing machine in the "active zone" of this module mock-up in Boeing's Huntsville facilities. In the background, Phil Hedges busies himself at a work control station in the mock-up's buffer zone, which separates the active zone from the quieter crew quarters.
Boeing



node outfitting, hardware and software for data management system, the communications and tracking system, the guidance, navigation and control system, extravehicular activity systems, the propulsion system, the thermal control system and associated software.

Major McDonnell Douglas subcontractors are: IBM, Lockheed, RCA, Honeywell, and Astro.

Phase I of the Work Package 3 contract, managed by Goddard Space Flight Center, calls for General Electric (GE) to provide a free-flying, unmanned, polar-orbiting platform which will carry scientific experiments in Sun-synchronous or other near-polar inclination orbits, and two attach points, including a pointing system, for accommodating scientific instruments on the manned base.

GE is also responsible for integration of the flight telerobotic servicer to the space station, appropriate space station information system activities, associated software and for planning NASA's role in satellite servicing. Additionally, GE is responsible for defining requirements and interfaces for a satellite servicing facility. TRW is GE's team member.

Phase I of the Work Package 4 contract, managed by the Lewis Research Center, calls for Rocketdyne to design and fabricate the space station electric power system. This system includes power generation and storage, management and distribution of electrical power and associated software. The electric power system, using photovoltaic solar arrays and batteries, is required to have the capability to deliver 75 kw of electric power.

In Phase I, Rocketdyne is also responsible for providing solar arrays, battery assemblies and common power management and distribution components for the polar platform and for performing a proof-of-concept test for a possible future solar dynamic power system utilising the Brayton cycle system.

The Rocketdyne team members are: Ford Aerospace and Communications, Harris Corporation, The Garrett Corporation, General Dynamics, and Lockheed.

Budget Deficit Casts Doubt on Station Future

The US Government's financial crisis poses a serious threat to NASA's space station plans and although the winning contractors have been announced there is at present no firm indication of the funding they will receive over the next two years.

NASA space station spending was planned at over $700 million in fiscal year 1988 and $1.8 billion for the following year. However, as a result of the US budget deficit these levels will almost certainly be reduced.

NASA has been considering various options to accommodate this, including extending the schedule (an initial extension would put back the first space station element launch by 12 months to 1995) or scaling down the station in various ways. The most drastic solution could lead to shelving the programme altogether.

SATELLITE DIGEST – 208

Robert D. Christy

Continued from the December 1987 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

CHINA 21, 1987-75A, 18341
Launched: 0715, 11 September 1987 from Jiuquan (Shuang Cheng Tse) by CZ-2 (Long March 2).
Spacecraft data: Satellite with a recoverable capsule, length around 5 m and diameter around 2.5 m and mass around 2 tonnes.
Mission: Possibly a remote sensing payload. The return capsule was recovered in Sichuan Province of China at 0500 on 17 September. The remainder of the vehicle re-entered on 4 October.
Orbit: 206 x 310 km, 89.66 min, 63.00 deg

COSMOS 1881, 1987-76A, 18343
Launched: 0206, 11 September 1987 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical, camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 231 x 274 km, 89.56 min, 64.77 deg, manoeuvrable.

COSMOS 1892, 1987-77A, 18348
Launched: 1030, 15 September 1987 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 21 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 256 x 278 km, 89.92 min, 82.34 deg

AUSSAT K-3, 1987-78A, 18350
Launched: 0045*, 16 September 1987 from Kourou by Ariane 3 (V19).
Spacecraft data: Cylindrical, spin-stabilised vehicle, approx 6m long and 2.2m diameter. The mass is 650 kg.
Mission: Australian, domestic communications satellite with Ku-band transponders.
Orbit: geosynchronous above 164 degrees east

EUTELSAT 1 F-4 (ECS 4), 1987-78B
Launched: 0045*, 16 September 1987 from Kourou by Ariane 3 (V19).
Spacecraft data: Box-shaped, three-axis stabilised body, approx 2 m on each side, with a 14 m span solar array. The mass is 700 kg.
Mission: European communications satellite.
Orbit: geosynchronous above 10 degrees east.

COSMOS 1883-1885, 1987-79A-C, 18355-18357
Launched: 0254, 16 September 1987 from Tyuratam by D-1-e.
Spacecraft data: not available.
Mission: Single launch of three navigation satellites in the Global Navigation Satellite System (GLONASS).
Orbit: 19108 x 19151 km, 675.71 min, 64.89 deg.

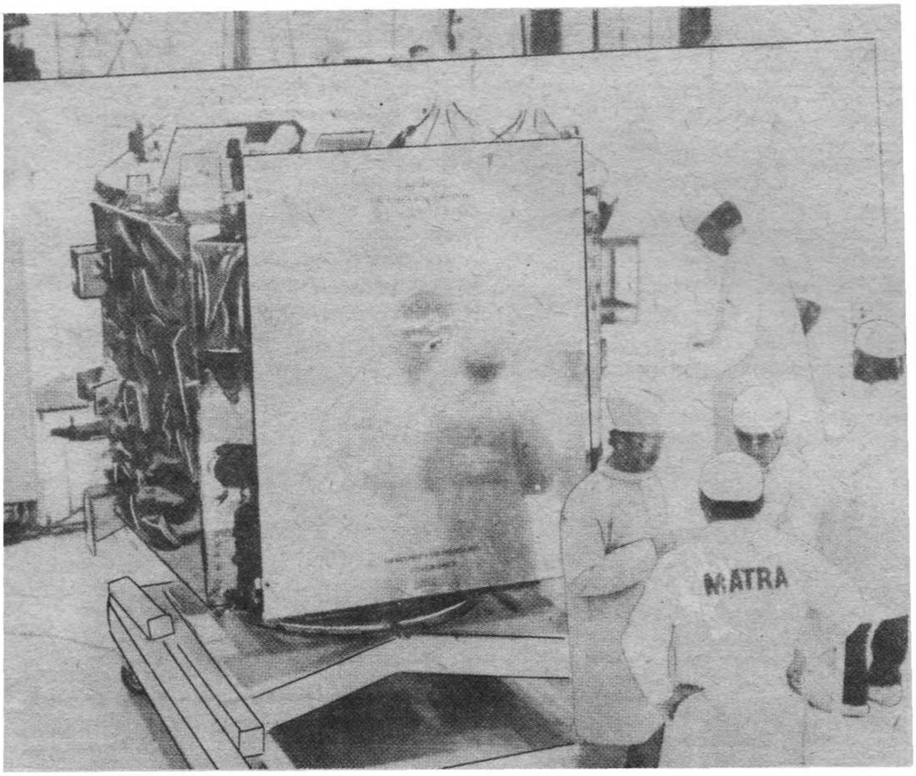
OSCAR 27 & OSCAR 28, 1897-80A&B, 18361&18362
Launched: 1923, 16 September 1987 from Vandenberg AFB by Scout.
Spacecraft data: Transit-type navigation satellites.
Mission: Pair of Transit-type navigation satellites placed into orbital storage for use when needed.
Orbit: 1017 x 1185 km, 107.35 min, 90.32 deg.

PROGRESS 32, 1987-82A, 18376
Launched: 2344*, 23 September 1987 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried fuel and supplies to the resident crew of Mir/Kvant. It docked with Kvant's rear port at 0108 on 26 September. At 0409 on 10 November it undocked, drew away to 2.5 kilometres distance and then re-docked 98 minutes later to test new computer software aboard Mir. It undocked again at 1925 on 17 November and its retro-rocket was fired at 0010 on 18 November, leading to a destructive re-entry above the Pacific Ocean.
Orbit: Initially 186 x 250 km, 88.80 min, 51.62 deg then by way of a 212 x 277 km transfer orbit to a docking with Mir in an orbit of 297 x 355 km.

COSMOS 1887, 1987-83A, 18380
Launched: 0050, 29 September 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may have been carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Biological satellite, the payload of which included monkeys, rats, fish and plants. It landed at 0403 on 12 October in the Yakutsk area after overshooting the normal Khazakhstan recovery area.
Orbit: 216 x 383 km, 90.50 min, 62.82 deg.

COSMOS 1888, 1987-84A, 18384
Launched: 0509, 1 October 1987 from Tyuratam by D-1-e.
Spacecraft data: A stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Luch series communications satellite providing continuous telephone, telegraphic and television links both within the USSR and abroad. It may also be providing tracking support to Earth orbiting spacecraft by providing radio coverage while they are out of communication with normal ground stations.
Orbit: geosynchronous above 80 degrees east.

COSMOS 1889, 1987-85A, 18394
Launched: 0830, 10 October 1987 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a



The ECS 4 satellite during preparation prior to launch

Campus in Orbit

The International Space University, founded in 1987, is planning its first academic session for July-August 1988 with an intensive nine week study programme devoted to all aspects of space from engineering and science to policy and law studies.

The ISU will attract students from all over the world, bringing them together in the formative stages of their careers and educating them across all fields important to space development.

In the longer term student experiments will be performed on board orbiting space stations and the foundations laid for the first students in space. The ultimate goal of the ISU is the establishment of permanent campus facilities in orbit.

The ISU has achieved widespread support, with pledges of money and students from China, Japan, Europe, the USA and Canada. An appeal to raise £35,000 for the sponsorship of six British students to attend this summer was launched in November by Mr. Roy Gibson, former Director General of both the European Space Agency and British National Space Centre.

spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 348 x 415 km, 92.21 min, 69.99 deg.

UPDATES:

1974-81A Molniya-1 (28) decayed on 29 December 1985 after 4084 days.
1975-9A, Molniya-2 (12) decayed on 4 July 1985 after 3800 days.
1975-121A, Molniya-2 (15) decayed on 7 March 1987 after 4098 days.
1975-125A, Molniya-3 (4) decayed on 30 July 1986 after 3868 days.
1976-74A, Molniya-1 (35) decayed on 29 May 1987 after 3962 days.
1982-7A, Cosmos 1335 decayed on 5 April 1987 after 1892 days
1985-109E, OEX Target decayed on 2 March 1987 after 460 days.
1987-13A, Soyuz-TM 2 undocked from Mir at 2034 on 29 July, and landed at 0154 the following day after 174 days in orbit.
1987-21A, Cosmos 1824 re-entered on 22 April 1987 after 55 days.
1987-43, USA 22-25 was launched from Vandenberg AFB, not Cape Canaveral.
1987-46A, Cosmos 1847 re-entered on 22 July after 57 days.
1987-52A, Cosmos 1860 split into several parts on 20 July 1987 and its nuclear-reactor power source was boosted to a 901 x 966 km orbit.

Longer Missions for Spacelab

NASA is assessing the possibility of flying all future Spacelab missions on the orbiter Columbia. This would allow configuring Columbia for increased on-orbit stay time and optimum use of orbiters Atlantis and Discovery, both of which have greater ascent lift capability, *writes Roelof L. Shuiling.*

The move follows NASA's recent decision to increase the space shuttle's landing weight limit from 211,000 pounds to 230,000 pounds. This has been made possible due to an ongoing structural analysis and the additional review of aerodynamic forces encountered by the shuttle orbiter during atmospheric manoeuvres prior to landing.

NASA associate admistrator for space flight, Rear Admiral Richard H. Truly, said: "The total space shuttle performance capability requires a balance between lift capacity to orbit and the allowable return weight during re-entry and landing. This new capability will improve this balance and add considerable flexibility and efficiency to our Space Transportation System.

"Our initial analysis indicates that this change will allow the shuttle to carry a cumulative weight in excess of 100,000 pounds of additional payloads into orbit through 1993. The additional downweight capability will also provide an important balance between delivery and return cargoes at the space station orbit of 220 nautical miles," Truly added.

Only certain flights on the shuttle manifest had been impacted by the landing weight restriction and the first flight planned to take advantage of the additional capability is STS-32, which is scheduled to fly the ASTRO-1 mission in the summer of 1989.

Additional payloads to be added to this and other missions are being reviewed and will be assigned when the next shuttle manifest is issued.

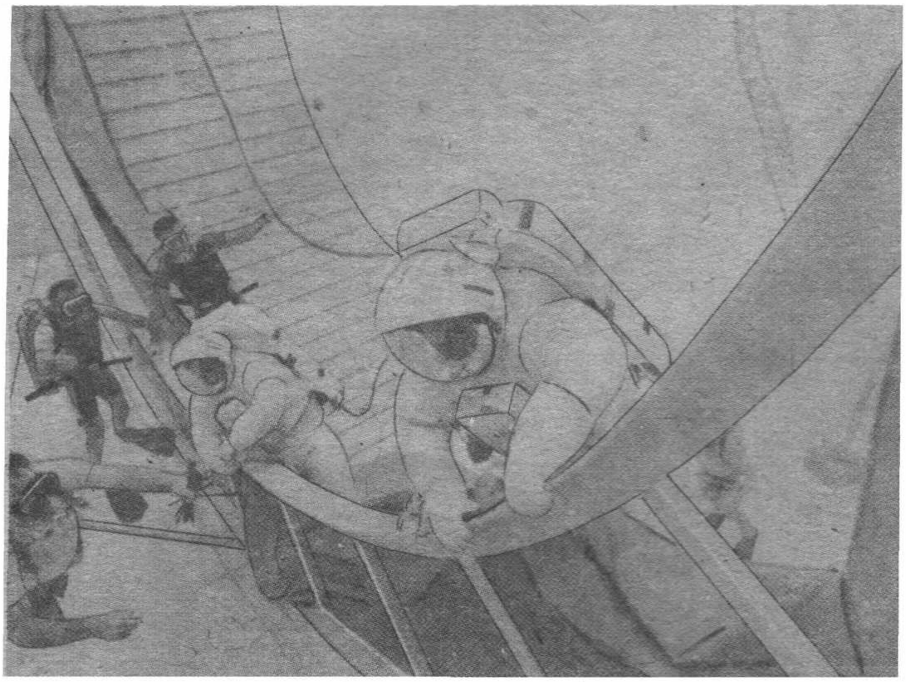
Control Package for X-ray Satellite

Ferranti of the UK has completed development and delivered a flight standard gyro package to MBB, W. Germany, for use on Rosat – an astronomy research satellite. The gyro unit and its associated electronics unit are key components in the spacecraft's three-axis attitude control and stabilisation system.

Rosat, scheduled for launch in about two years, is funded jointly by the British, German and American governments. Its prime objective will be to conduct the first X-ray imaging survey of the complete sky.

INTERNATIONAL SPACE REPORT

ET Tank Evaluated for Gamma Ray Telescope



A study aimed at exploring the possibility of converting one of the US space shuttle external fuel tanks into a pressure vessel capable of housing a giant gamma ray telescope is being carried out at NASA's Marshall Space Flight Center.

As part of the $92,000 study contract, engineers from Martin Marietta (which manufactures the external tank) worked with researchers at Marshall to build a mock-up of a portion of the base of an external tank.

The mock-up was placed into the Center's Neutral Buoyancy Simulator (a 40-foot deep water tank) where attempts are being made to perform the tasks (pictured left) which would be necessary in space to convert the external tank into a housing for the telescope.

The tank, already a pressure vessel designed to hold liquid hydrogen and liquid oxygen, has walls which are thin enough to be penetrated by gamma rays. The main task is to remove internal fittings to prevent gamma ray blockage and make space for additional equipment.

New Euro Weather Satellites

British Aerospace Space and Communications Division has been awarded two European Space Agency study contracts, with a total value of over £150,000, for its second generation of European Meteosat weather satellites.

They comprise a Spacecraft Systems Study and a Study for a Microwave Sounder – one of three principal instruments planned for the new Meteosat satellites expected to commence service in geostationary orbit by the mid 1990s.

Meteosats, operated by the European weather satellite organisation, Eumetsat, provide meteorologists with valuable data including the pictures which have become a regular feature of television weather forecasts. In addition to producing raw images and relaying processed data, Meteosat also relays data collected by remote Earth stations, weather balloons, buoys at sea, etc.

The new system will help to improve the accuracy of weather forecasts by providing better pictures and more data, including temperature and humidity profiles of the atmosphere.

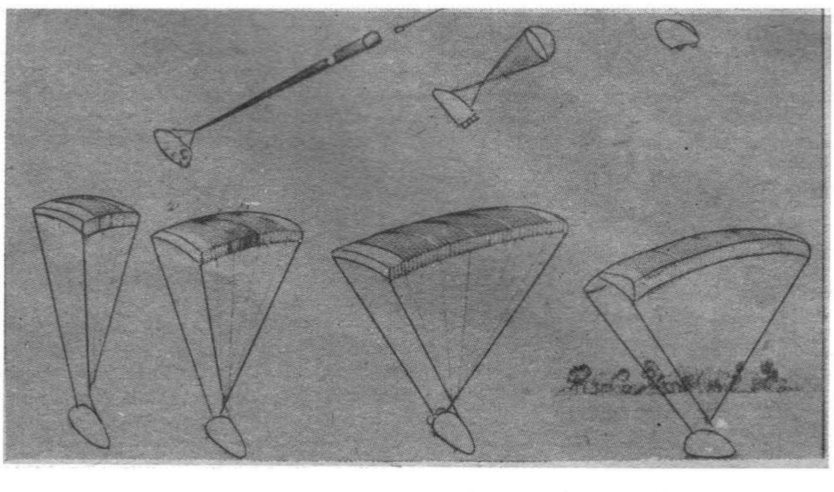
Recovery System Studies

Studies of an advanced recovery system to be used in conjunction with future launch vehicles are to be conducted by Pioneer Systems, Inc., for NASA's Marshall Space Flight Center under a $3,000,000 contract.

Phase one of the study, which has already been completed, showed the potential of such a system for large, high-value, reusable launch vehicle components. The applications may also extend to other programmes, such as orbiting payloads and the space station. A land-based recovery system would eliminate concerns about salt-water corrosion damage to high value components and would simplify their return to the launch site.

Phase two of the study will involve experiments to demonstrate the recovery system's capability. It is anticipated that, through a series of drop tests from aircraft, the capacity of the selected system will be shown to provide precision soft landing for a 20,000 pound subscale payload with applications to full-scale payloads, weighing 60,000-70,000 pounds.

An artist's concept depicting the principal stages of the proposed advanced recovery system that is under study for NASA. *Pioneer Systems*



SOVIET SCENE

Space Hardware Displayed

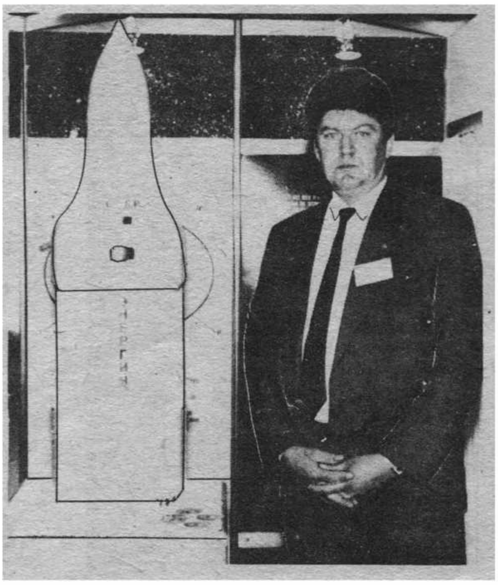
by Peter Bond

There has been considerable discussion in *Spaceflight* recently concerning the Energia booster and the future development of the Mir orbital complex. Further information, on which the accompanying illustrations are based, was presented by the Soviets at the recent IAF Conference in Brighton.

Figure 1 shows the payload as it was presented on a model of Energia at Brighton – the payload was barely visible on Soviet TV coverage of the first Energia test flight.

Soviet announcements gave the height of the Energia core stage as about 60 m and the core diameter as 8 m. Assuming the diameter of the core is the more accurate figure, the scale of the model gives a height of 61.3 m for the core, including the rocket nozzles at the base. This means that the Energia core is about the same width as the US space shuttle external tank, but considerably longer. Similar calculations give the total height of the first stage strap-on booster as 41.6 m, the height of the cylindrical section as 35.2 m and the diameter as 4 m.

It is clear that the four boosters are not symmetrically located around the core. Instead, they are clustered towards the side opposite the payload. This means that there is plenty of room for a Soviet shuttle of similar size to the US version to be strapped onto the core. There is also sufficient room for four extra strap-ons around the core should the Soviets want to expand Energia's potential at some future date by placing a heavy payload on the nose of the core.



Soviet cosmonaut Valeri Ryumin beside a scale model of the Energia rocket displayed at SPACE '87 *P J.Fulford*

The location of the large panniers near the top and bottom of each strap-on booster takes on greater significance when seen against the background of a recent Soviet announcement that the boosters are fully recoverable and designed to parachute separately back to Earth. The core stage is also described as reuseable, returning to Earth by parachute in three sections.

The strap on payload was said to be a full size mock-up, presumably with a weight of around 100 tonnes. According to the model at Brighton, the payload was 40.6 m in length, with a cylindrical core 4.5 m in diameter. The satellite section in the nose is slightly wider, about 4.8 m across and 13.9 m in length from nose cone to base. Note the two booster rockets at its base on either side of the payload core. They measure 8.5 m in length and 1.4 m in diameter. Presumably these are the units which failed and caused the dummy to plunge into the Pacific instead of reaching orbit. It does indicate, however, that the Soviet shuttle, when it flies will need to have some form of rocket power in order to boost itself into orbit.

Figure 2 shows the layout of the Roentgen astrophysical observatory which is the main scientific payload aboard the Kvant module. The main complex is the Pulser X-1 experiment which consists of five X-ray telescopes and the world's biggest specialised detector of cosmic gamma rays. Also on board are the West German High Energy X-Ray Experiment (HEXE); the European Space Agency's gas scintillation proportional spectrometer which studies rarefied gas at extremely high temperatures in distant clusters of galaxies; and a telescope with shadow mask (TSM) which was developed in Utrecht and Birmingham for locating and imaging X-ray sources. Data are beamed back to Earth and distributed to researchers on magnetic tape. Altogether, X-ray sources in the range

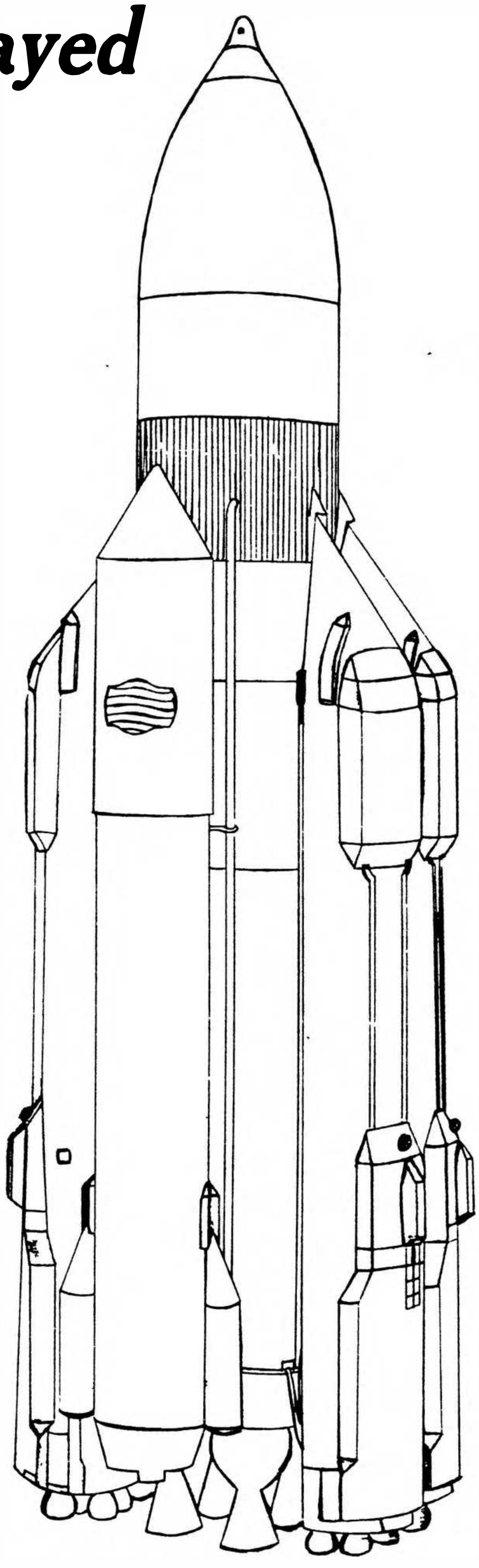
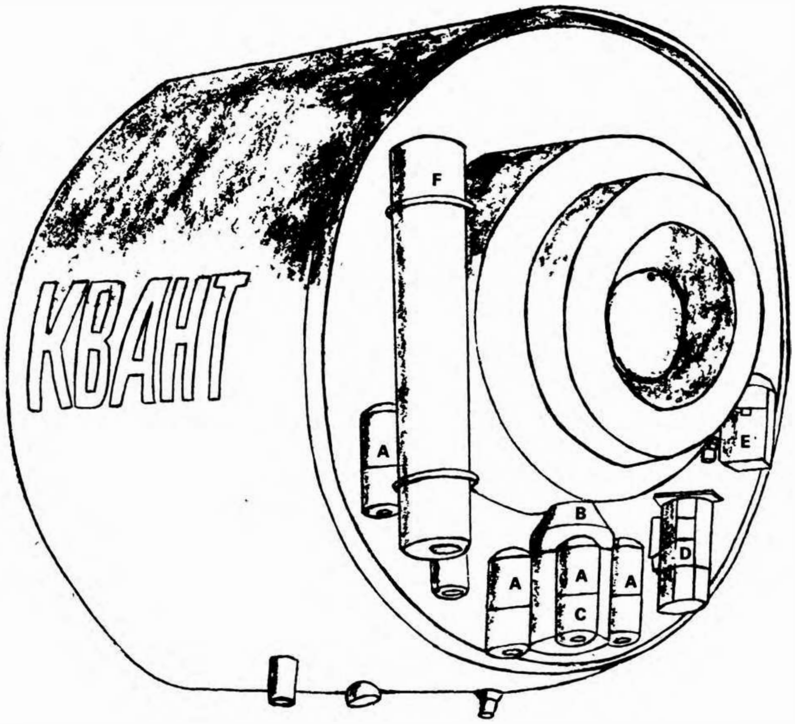
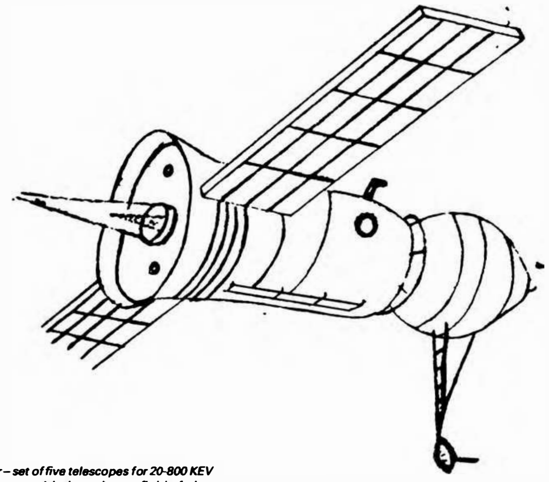


Fig 1 Energia *P.R.Bond*

SOVIET SCENE

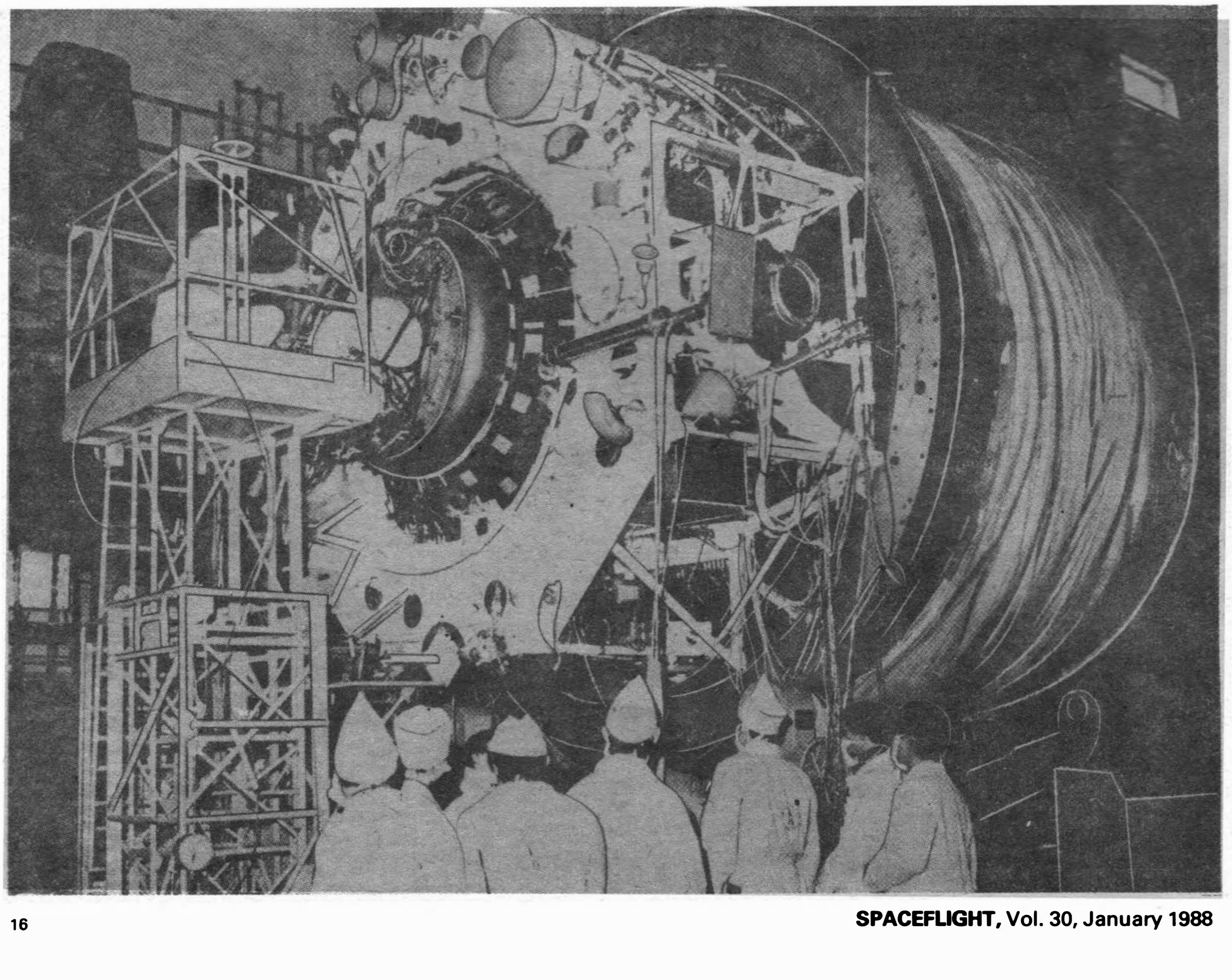




A. Pulsar – set of five telescopes for 20-800 KEV energy range with three degree field of view (USSR) B 'Glazar – telescope for UV spectrometry of stars in 1150 – 1350 Å spectral range with 1-2 Å resolution (USSR) C For 20 – 1300 KEV energy range with 180 degree field of view and 1 ms time resolution (USSR) D GSPS – spectrometer with 10 – 3 per cent resolution, three degree field of view, for 1-100 KEV energy range (USSR, ESA) E HEXE – spectrometer with 30 – 12 per cent resolution, 1 6 degree field of view, for 15 – 200 KEV energy range (FRG, USSR) F TSM – coded mask telescope for imaging in 2 – 20 KEV energy range, with seven degree field of view and two minute resolution (Neths., UK, USSR)

Fig. 2. The Roentgen astrophysical complex incorporated into the Kvant module. *P.R. Bond*

Technicians inspect work during construction of the Kvant astrophysical module which is now in operation with the Mir complex. *Novosti*



SOVIET SCENE

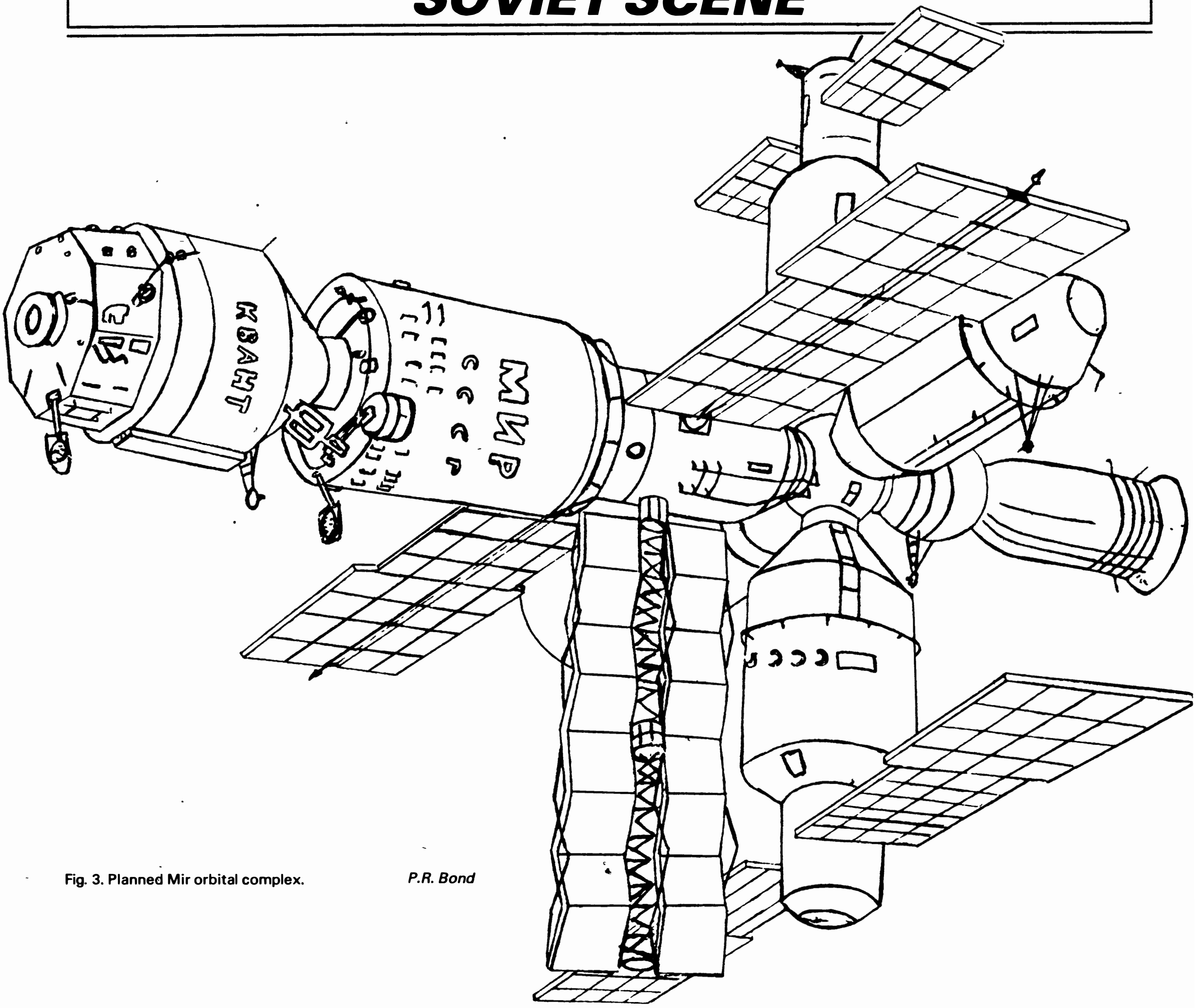


Fig. 3. Planned Mir orbital complex. *P.R. Bond*

2-800 kiloelectronvolts can be studied with the complex.

There is also a Glazar ultraviolet telescope which was developed in cooperation with Swiss astronomers. It is used to study the violent processes taking place in the nuclei of galaxies and quasars. Although its mirror is only 40 cm across, it is made more sensitive by an electronic amplifier. Rolls of film are brought back to Earth by returning cosmonauts.

The Roentgen complex was developed over seven years and many experimenters assumed that the observatory was originally to be attached to a Salyut space station. First observations took place early in June 1987, although the Glazar telescope was not installed until the end of June.

A recent Soviet illustration of the fully developed Mir complex (Fig. 3) shows the Mir base unit with the Kvant scientific module and a Soyuz TM approaching to dock at the rear. The forward docking adaptor is occupied by a Progress cargo ship. A Progress craft has never docked at the front end of a Salyut or Mir, but perhaps that will change as the need for cargo used in the experimental laboratories takes on a more important role.

The forward adaptor is also occupied by: two heavy Cosmos type modules, both equipped with solar panels; one Kvant style module with its service pod still attached; and another large module without solar panels. Those modules with their own power supply will probably contain experiments which need large amounts of power (e.g. materials processing) and may even be able to undock and become free-flying once loaded with raw materials by the crew. There is no evidence, however, of cargo recovery sections on any of these modules, which raises the question of how results of the experiments will be brought back to Earth. A Soyuz TM can only carry 150 kg of freight back to Earth.

Crew Set for Return at End of Year

The record-breaking Mir space station crew of Yuri Romanenko and Alexander Alexandrov were expected to return to Earth at the end of the year.

Commander Romanenko passed the 300 day point of his marathon mission on December 2, giving him a total of 329 consecutive days in space up to December 31.

A new crew, whose names were announced in early December (see p.18), is expected to extend the long-stay record by remaining on Mir for a full year.

Glavcosmos Marketing in Europe

New Mir Crew Given in Advance

The names of the prime and back-up crews for the new mission to Mir were announced on December 9, well in advance of the expected launch before the end of the year.

Prime crew is Col. Vladimir Titov (commander) accompanied by Musakhi Manarov (flight engineer); and Anatoly Levchenko (researcher).

Back-up was announced as Col. Alexander Volkov (commander), Alexander Kaleri (flight engineer) and Alexander Shuchukin (researcher).

The Soviet Union, through its Glavcosmos, Licensintorg and Soyuzkarta organisations, is stepping up the marketing of launch vehicle and spacecraft systems and services in Europe.

Recent efforts of the Soviet authorities to sell space know-how to Western countries include:

- Visits by Inmarsat and British Aerospace Dynamics delegations to the Proton launch facilities at the Baikonour-Leninsk complex.

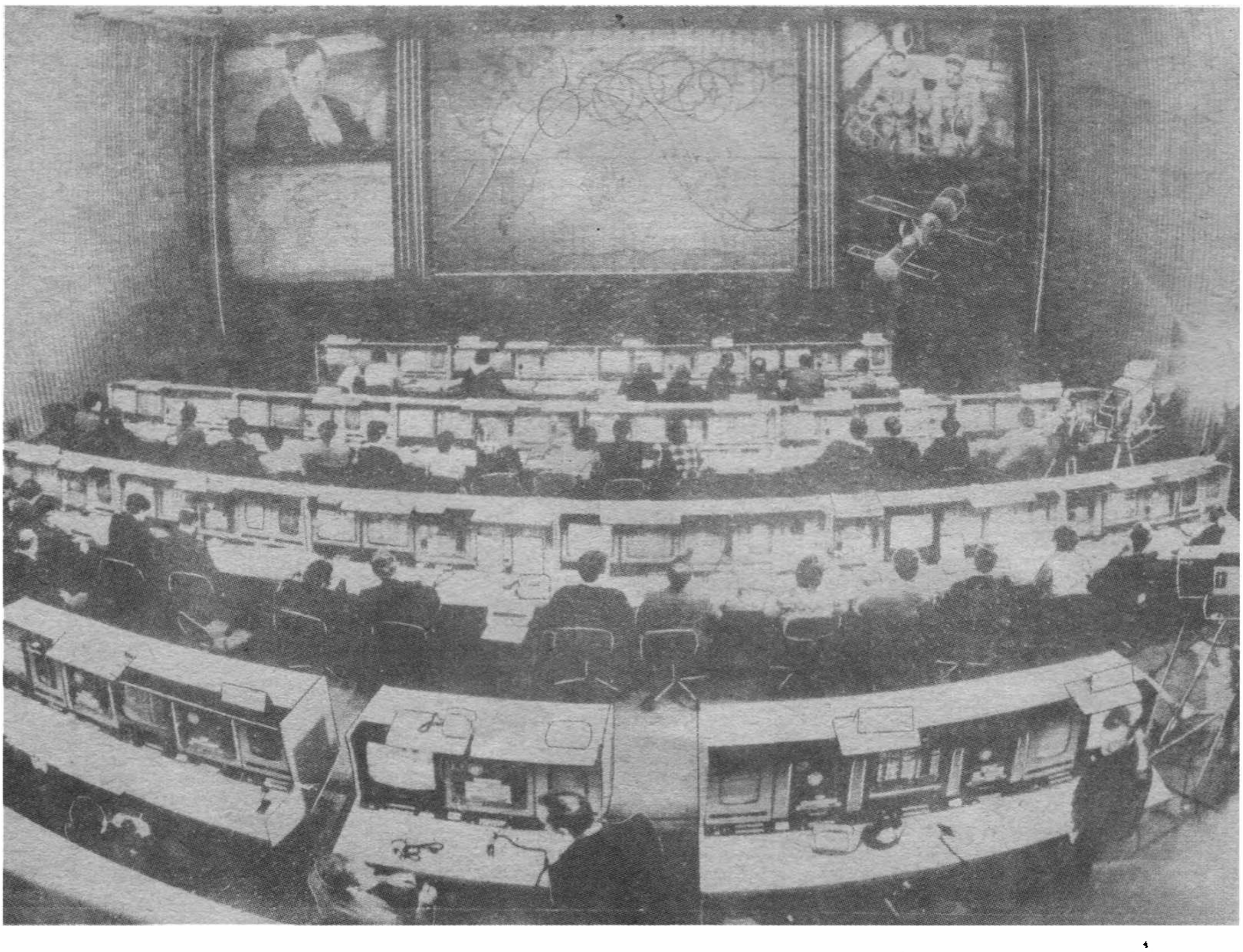
- London-based Jardine Granville (Interplanetary), agent for Licensintorg except in the United States, has signed three launch reservation agreements for the Proton rocket.

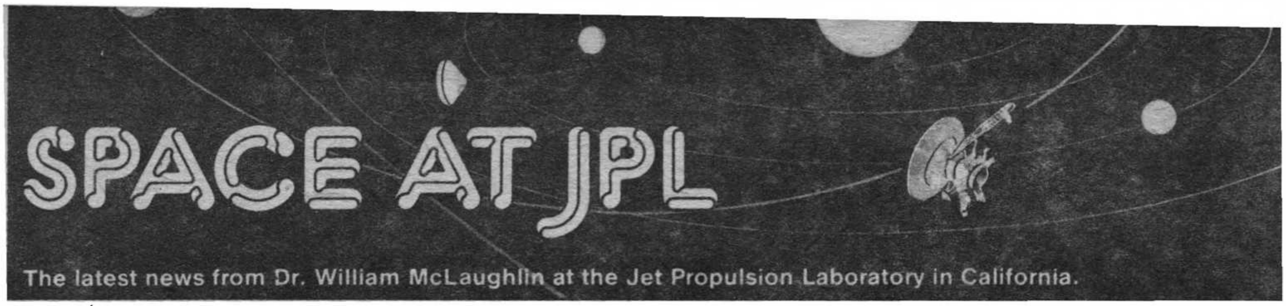
- Finnish company FM Projects (established by Finnmap, a specialist in aeronautical mapping/survey, and by Finnmart) has signed a marketing agreement with Soviet Soyuzkarta; it will be the exclusive distributor of Soyuzkarta space photographs of Europe; FM Projects has announced that it will offer five metre resolution photographs taken from Mir and Cosmos cameras and that these photographs will be available within "one week".

- Glavcosmos is participating in a space exhibition at Brussels during 1988 (from March to May); it will present full-scale mockups of the Mir-Kvant complex and also of the Photon spacecraft (for microgravity experiments).

- Glavcosmos and IKI (Institute for Space Research) are negotiating with ESA the use of Mir opportunities to test the inflatable large antenna, prepared for the Quasat observatory in space.

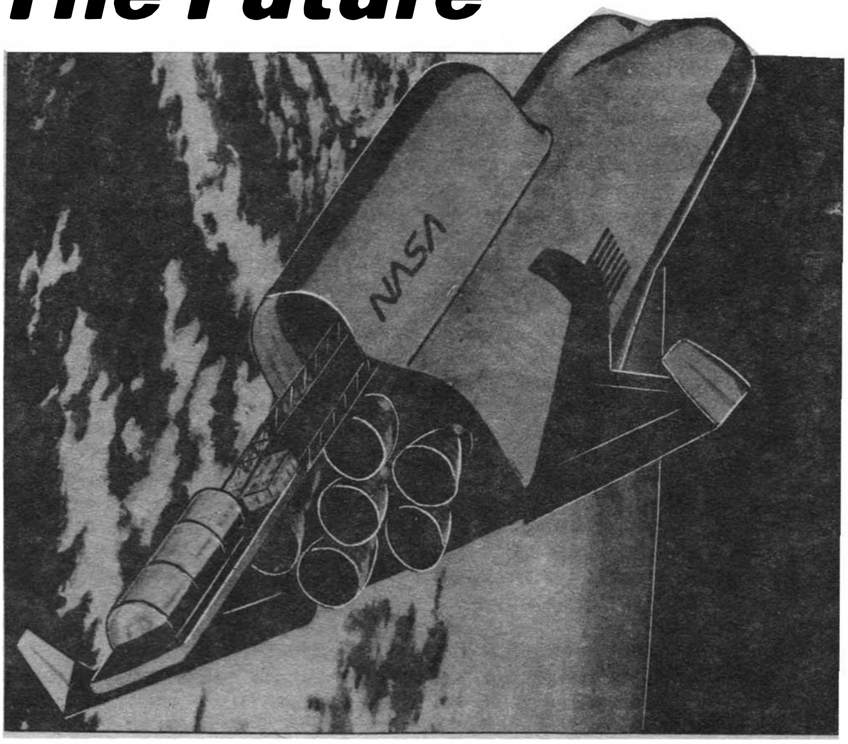
Detailed view of Soviet space flight control and coordination centre during Mir operations *Novosti*





Charting The Future

The exploration of space has always been a future-oriented undertaking. In the best of times, the focus is upon *doing* the exploration – making an agreed-upon set of projects work. Such was the case during the Apollo years when a series of NASA missions greatly increased our knowledge of the Moon and planets, and this golden age spilled over into the following decade. In more uncertain times (a few years following Sputnik and the post-Challenger period are the most obvious examples for the US space programme), the question becomes: what should the future be?



Artist's impression of a Shuttle C orbiter, displaying multiple engines, tip-fin wings and the payload canister arrangements. *NASA*

A look at key issues within the NASA community took place at the 34th Annual Symposium of the American Astronautical Society in Houston, Texas on November 3-5. The gathering was distinguished by the presence of several of the individuals who are responsible for charting the future, and we will ride along on their vision by briefly surveying selected topics from the symposium. Your correspondent cannot, alas, qualify for the distinguished category but did enjoy presenting a summary of planetary-mission plans. Since these prospects should be familiar to the reader, suffice it to say that the summary concluded with listing the British Interplanetary Society's Daedalus starship conception as a possibility for a twenty-first century mission.

Admiral Richard Truly, NASA's Associate Administator for Space Flight, reiterated that "the number one job today is to get the Shuttle flying again". He said the goal is still to achieve a first launch in June 1988; there is yet some slack but it is decreasing. Morale is high, much up from last year, and "when this system is flying again, it will be in far better shape than it was before the accident". Truly felt that a flight rate of 12 to 14 Shuttle launches per year is achievable if the programme gets the required resources and facilities. The fourth orbiter is now about 25 per cent complete at the Palmdale, California plant of Rockwell and should join the fleet in the winter of 1991-92. NASA is committed to a mixed fleet of launch vehicles, Shuttles and Expendable Launch Vehicles (ELVs), "with the great majority of ELVs from the commercial sector".

The Director of NASA's Marshall Space Flight Center, J.R. Thompson, Jr., listed the main engine and the solid rocket motor, in that order, as the biggest reliability issues for Shuttle. This calendar year the equivalent of 23 Shuttle missions have been completed on the main engine. The key to reliability is "to test, test, test, even after Shuttle flights resume." Thompson is pleased with the redesign of the solid rocket motor and is more worried about carefully controlling the process by which the rockets are built than concerns over their design. The redesign should be employed for approximately the next five years. Some effort is directed toward looking at pump-fed or pressure-fed liquid boosters to replace the solids. The obvious advantage of liquids is that they can be shut down in flight if a problem develops.

Three proposed propulsion systems beyond the present Shuttle were discussed: The Shuttle-C, the Advanced Launch System (ALS), and The National Aero-Space Plane (NASP).

The Shuttle-C, "C" denotes "cargo", would be an unmanned vehicle capable of putting about 100,000 lbs into orbit from the Kennedy Space Center (the current Shuttle capability is approximately 50,000 lbs, down from 65,000 lbs prior to the Challenger accident). The vehicle could be ready for use in the 1993 timeframe. Thompson pointed out that the Shuttle-C would have the advantage of being based upon existing technology. It would not be competitive with the Advanced Launch System but would serve as a heavy-lift vehicle until more advanced systems were in place.

The ALS was discussed by Colonel John R. Wormington, the Director for Advanced Studies in the Air Force Systems Command. He emphasised the requirement for simplicity in such a system in order to increase reliability: "stop making the launch vehicle an engineering extension of the payload." The ALS is now in the conceptual development phase and is being supported by a broad spectrum of industrial contractors in order to insure that the flow of ideas is wide ranging. The goal is to produce a reliable system that can deliver a payload to low Earth orbit at a cost of about $400 per pound. The schedule foresees an operational vehicle by the mid to late 1990's. In addition to simplicity of design, Wormington said that a key to reliability was not to push the engine to the limit of its operating capacity but to have the discipline to back off and operate at less than maximum performance. He said that he would also like to see a launch system built, if possible, with-

out gantries, towers or platforms. If you have a platform, you will put a man on it and find a job for him to do, increasing cost.

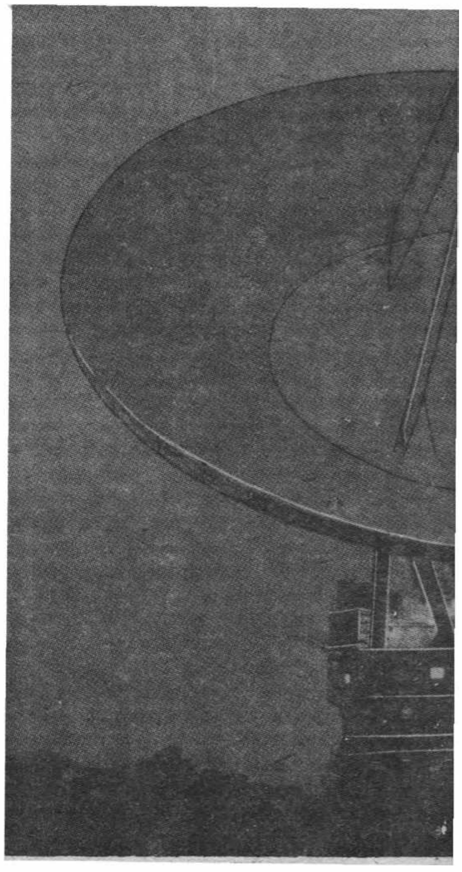
Chuck Yeager broke the sound barrier for the first time in history on October 14, 1947 flying in his Bell X-1 test aircraft. The famous X-15 began its series of flights in the late 1950's lifting not only itself but also aviation technology to new heights. Now, a programme is underway which may lead to the development of an X-30 aircraft to serve as a test bed which would provide the technological basis for hypersonic flight vehicles. These vehicles would have the capability to fly into orbit as well as race across the globe at hypersonic speeds. William M. Piland, Program Director of NASP at NASA Headquarters, said that an assessment milestone is scheduled for 1990 to see if the programme is sufficiently technologically advanced at that time to proceed with building the X-30. If not, technology development would be continued. If the decision were to go ahead, the aircraft could have a first flight as early as 1993. Two X-30s would be built; each would carry a two-person crew and be fully reusable for 150 flights. The aircraft would fly as a single stage to orbit, utilising airbreathing propulsion, and would even carry its landing gear into orbit. Piland emphasised the technology-development nature of the programme. The X-30 would not be a prototype or an operational system; it would lead to future spacelaunch vehicles and future hypersonic airplanes. The goals with regard to launch capability are to provide routine access to space and make an order-of-magnitude reduction in cost to orbit, the latter being difficult to achieve.

Dr. George Newton, who is the Chief of Advanced Programs and Technology in NASA's Office of Space Science and Applications, described how NASA's "Great Observatories" will span the electromagnetic spectrum with instruments of great capability: the Hubble Space Telescope (1989 launch), the Gamma Ray Observatory (1990 launch), the Advanced X-Ray Astrophysics Facility (FY 1989 new start being sought), and the Space Infrared Telescope Facility (future). Dr. Frank Jordan of JPL described QUASAT mission concepts. The astounding feature of this radio telescope, if flown, is the high resolution it would have for astronomical studies. Operating In conjunction with Earth-based radio telescopes, it would, in effect, synthesise a radio telescope with an aperture the size of its orbit and be able to resolve detail down to $3x10^{-5}$ arc seconds. For comparison, the Palomar 5m telescope resolves at not much less than 1 arc second; the Hubble Space Telescope should get better than 0.1 arc seconds; the Very Large Array (VLA) in New Mexico achieves $6x10^{-2}$ arc seconds; and the Very Long Baseline Array (VLBA), which will synthesise a continent-sized radio telescope, should resolve at the $5X10^{-4}$ arc second level. The technique of very long baseline interferometry (VLBI) has yielded astronomy's most effective tool for tracing structures in exquisite detail. The trichotomy of enhanced resolution, wide coverage of the electromagnetic spectrum and increased sensitivity are bringing a golden age of astronomy to us.

Meetings of quality like the Houston gathering and studies of the caliber of Dr. Thomas Paine's and Dr. Sally Ride's provide valuable material for NASA's planning process. But the Agency has recognised the need for systematising these looks into the future. John Aaron is the Assistant Administrator, Office of Exploration, and in this new NASA office will play an important role in determining future directions. He described his office as helping "to make the transition from *ad hoc* studies to formal institutional planning". The goal is to formulate a set of initiatives by 1992 and to proceed to develop them with Phase B studies.

Improved Deep Space Antennas

There are a multitude of ingredients contributing to the success of a space mission: sound spacecraft design and faithful construction, comprehensive science and mission planning and efficient data systems ... the list is much longer. One ingredient that is absolutely vital, but is often underappreciated in apportioning credit after a mission is successfully completed, is the tracking system which is used to command the spacecraft and receive data from it. For 25 years, the Deep Space Network (DSN), managed by JPL for NASA, has performed magnificently, time after time, by maintaining reliable lines of communication that electronically tether distant spacecraft to Earth.



The DSN has three tracking sites spread longitudinally around the world: in California, Australia and Spain. Four major radio antennas are located at each site. One has a diameter of 26m, two have 34m diameter, and the largest, formerly sized at 64m, has been extended to 70m at two sites, and similar construction is underway at the Goldstone, California location. The upgrade project is scheduled for completion by 1 June 1988 in order to support Voyager preparations for the encounter with Neptune in the summer of 1989.

Donald H. McClure, manager of the 64-Meter Rehabilitation and Performance Upgrade Project, said that in the mid-1970's the DSN began to examine options for improving the performance of their antennas, particularly the large ones. The first 64m antenna was dedicated at Goldstone in April 1966, and the Australian (Canberra) and Spanish (Madrid) 64m instruments were erected in July 1972 and January 1973, respectively.

The motivations for improving performance are several. Voyager 2 will take several thousand images at distant Neptune, and the improved DSN antennas will add to the impressive collection of aperture which is being assembled on Earth to catch this photographic bounty (also: 34m antennas will be electrically coupled, "arrayed", with the 70m antennas; the Very Large Array (VLA) of radio-astronomy telescopes in New Mexico will be arrayed with the Goldstone complex; the Parkes 64m antenna at Usuda, Japan will be brought into the Voyager 2 tracking network).

Navigation of Voyager (and Galileo) is done partly through the use of interferometric techniques which require the presence of natural radio sources, usually quasars, near the apparent path of the spacecraft. The increased sensitivity of the 70m antennas doubles the number of sources available to support this method of navigation.

The Pioneer 10 spacecraft (managed by NASA's Ames Research

Center) furnishes another example of a beneficiary of the increased tracking capability. In 1990, it will be at the limit of a 64m antenna (48 astronomical units for this spacecraft) but should still be capable of collecting and transmitting scientific data from this distant, unexplored region. A 70m antenna will be capable of extending the useful life of the spacecraft for three years and 10 astronomical units.

With these more powerful antennas on Earth, future spacecraft can reduce their onboard transmitter power or antenna size, or increase their data rates, thereby allowing a combination of mass savings or information increase to be built into the design.

Uplink capabilities are also improved with the new antennas. Thus, more power can be radiated toward a spacecraft in an attempt to command it during an emergency.

Radio-astronomy capabilities will be enhanced through the detection of fainter sources and increased resolution made available for mapping of planetary surfaces by radar techniques (100 km resolution at Venus could be improved to 60 km).

According to McClure, the two major options for improving DSN performance were to pursue the 70m route or to add additional 34m antennas to the system and array them with the 64m antennas, when additional sensitivity was required. In order to choose between these alternatives a cost-effectiveness study was instituted. The measure of performance was specified as one (then existing) 64m antenna: "one aperture unit". Analysis showed that a 34m antenna would cost $28.5 m per aperture unit while the 70m upgrade would cost $17 million per added aperture unit.

More power can be radiated toward a spacecraft in an attempt to command it in an emergency.

In terms of capability, a new 34m antenna would represent 0.35 aperture units, and so, arraying a 64m antenna with two 34m antennas would yield a system with a capability of 1.7 aperture units. The extension to 70m adds 0.53 aperture units to the 64m instrument, the equivalent of about 1.5 new 34m antennas. Clearly, on the basis of cost and performance, the option of extending the large antennas to 70m was indicated.

The 70m diameter was chosen because it is about the maximum that can be supported without making extensive changes in the drive system of the antenna to accommodate required operational velocities for antenna motion and the ability to function in high-wind environments.

The improved performance of the 70m antennas derives not only from extending their diameters by 6m but also by producing better surfaces. Before examining the nature of these engineering changes, it is useful to review the customary means by which antenna performance (and that of communications links in general) can be evaluated with regard to sensitivity.

The decibel, abbreviated "dB", is a unit used to compare two amounts of power. The "bel" root refers to the inventor of the telephone, Alexander Graham Bell. The difference, in decibels, between two sources of power is equal to ten times the logarithm (base 10) of their power ratio (where each power might be measured in watts – it doesn't really matter since the act of ratioing cancels units). Multiplication by 10 is customary and creates the "decibel" as opposed to the "bel". The decibel is also used in acoustic engineering where it represents about the smallest change in sound intensity that the ear can detect.

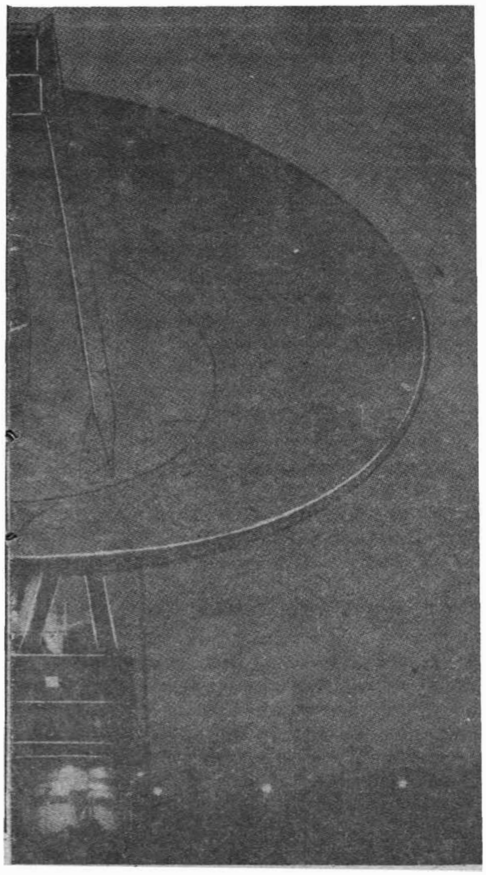
In enlarging an antenna from 64m to 70m, one gains 0.8 dB in performance; the logarithm of the ratio of the areas of the larger-to-the-smaller, times ten, yields this figure. The area of an antenna is the proper measure of the power it receives from celestial sources because the number of (radio) photons per second collected by the antenna is, of course, proportional to its area.

The utility of dB measures arises from the fact that in many cases of importance they permit additive calculations of performance (this is due to their logarithmic nature; a nature shared by the "bit" measure of amount of information in data systems and by the calculating tool of the previous generation, the slide rule).

An example of the additivity of dB gains is furnished by the present 64m conversion. The design goal of the conversion is to achieve a 1.9 dB improvement in antenna performance. The 1.1 dB improvement above the 0.8 dB gained through the increase in diameter comes from two sources: (1) making the surface of the antenna smoother – a closer approximation to its desired theoretical shape, and (2) changing the desired shape from paraboloidal (for the old 64m antenna) to a more efficient shape which distributes the received radio energy more evenly over the surface of the antenna. Factor (1) adds 0.6 dB while factor (2) supplies 0.5 dB. These performance figures are associated with energy received in the X-band range of frequencies – the frequencies at which most spacecraft return the bulk of their data to Earth. The performance gain from the 70m antenna at lower, S-band frequencies is 1.4 dB rather than 1.9 dB since the increased fidelity of the antenna surface has little effect at the lower frequencies (the associated longer wavelengths are not as sensitive to surface irregularities).

McClure said that the effort to construct a smooth surface for the antennas was a difficult undertaking. The average (rms) deviation from the desired shape (smooth paraboloid) of the surface of a 64m antenna was 1-1/4 mm, as measured at selected points. This was due to imperfections in each of over 800 panels comprising the surface of the antenna and to misalignment of the panels. All new panels were fabricated for the 70m dishes, 1272 per antenna, with an average total deviation of only 1/2 mm as a goal.

The testing of the antenna in Spain gave McClure and his colleagues a nasty surprise (this antenna was the first of the three to be upgraded: from July 1986 to July 1987). When the dB gain as a function of spacecraft elevation above the horizon was plotted, not only did it fail to achieve the design goal of an upward translation by 1.9 dB, but it also showed an inexplicable shape. The antenna panels had been aligned with the classical optical technique using a theodolite on a panel-by-panel basis. To gain insight into the problem, a new technique, microwave holography, was introduced. This method utilises a small 3m antenna in conjunction with the test antenna (70m); both instruments simultaneously observe a source (usually a convenient geosynchronous satellite), and a map of surface deviations is quickly and accurately produced. Using an adjusting tool, a technician can then move the support points on each panel to bring it into



"Spain at dawn". The rebuilt 70m antenna at the Madrid site of the Deep Space Network was brought onto line in mid 1987 after one year's work invested in upgrading it. *NASA/JPL*

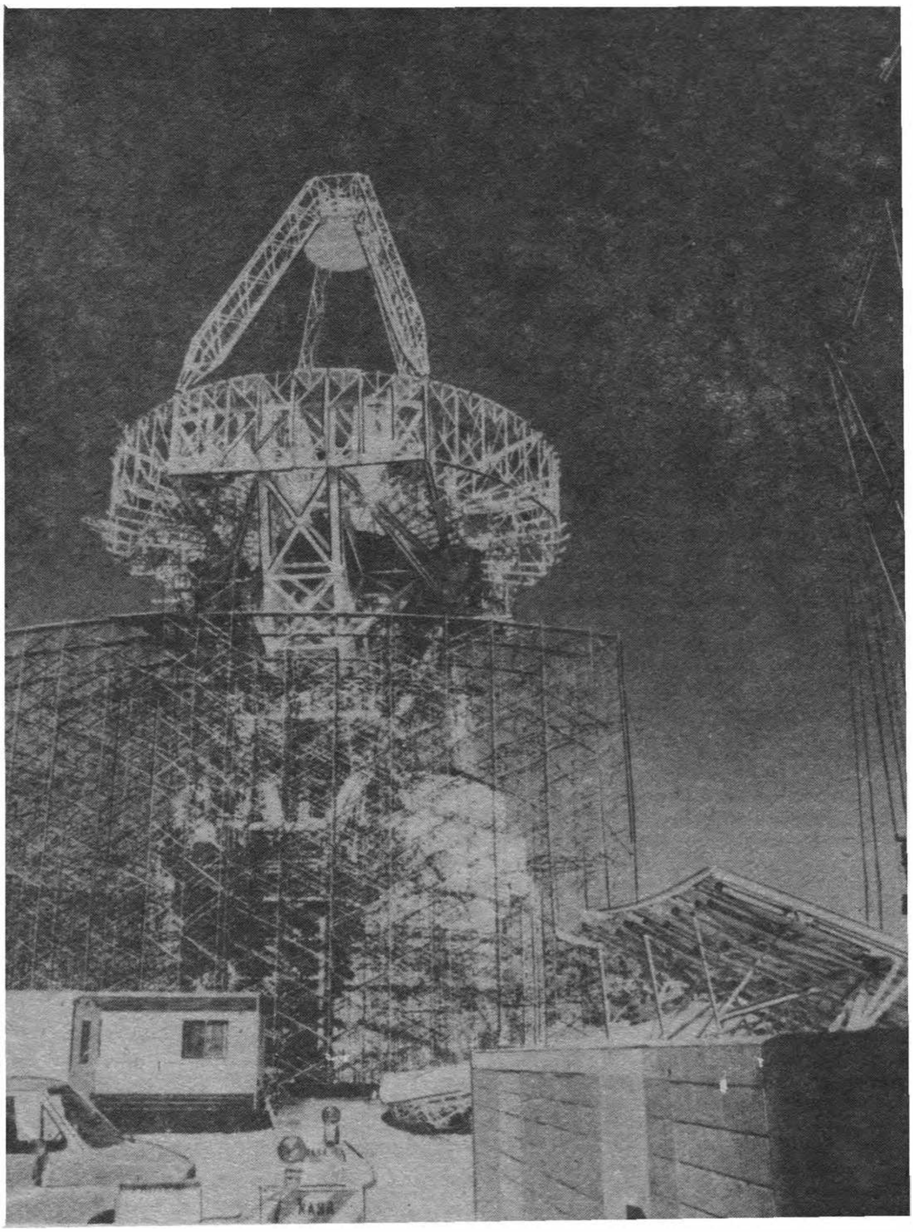
closer conformance with the desired surface.

In this manner, the antenna in Spain was tuned until its gain actually exceeded the 1.9 dB goal; it is currently about 2.2 dB higher than its 64m predecessor. The antenna in Australia took just under nine months to convert (February through October of 1987). Theodolite alignment was employed for a first, crude approximation, followed by refinement with microwave holography. The Goldstone antenna was taken down on 1 October 1987 and, as mentioned above, is scheduled to be converted by June 1 1988.

The conversion project is characterised by McClure as having a "decidedly international flavour." The microwave holography services are provided by Eikontech Limited of Sheffield, England, while the high-precision surface panels have been manufactured in Italy. The 8-meter diameter subreflectors (each is analogous to the secondary mirror in an optical telescope) were manufactured in Spain to a tolerance of 0.0015 mm; not many places in the world can machine an object this large with such precision. The steel work for each antenna has been done in the host country.

With successful conversions in place in Spain and Australia, McClure, who became project manager in 1982, views the prospects for the Goldstone conversion with optimism. The task is, indeed, the renewal of an old friendship, since he was field engineer during installation of the original 64m antenna at the site.

The structure of the former 64m antenna at Goldstone, California awaits its new 70m surface designed to provide greater grasp for tracking the faint signals of interplanetary spacecraft. This photograph was taken in October 1987; conversion is scheduled for completion by June 1988. *NASA/JPL*



Ulysses Pr

Ulysses is a joint ESA/NASA mission to explore solar phenomena within two astronomical units from the Sun, at high solar latitudes. The Challenger accident postponed the planned May 1986 launch, and now the European-built spacecraft is scheduled for launch aboard a Space Shuttle in October 1990. Willis Meeks of JPL, the NASA project manager – Derek Eaton serves as ESA's project manager for Ulysses – said that the launch delay posed significant management problems, but this international project is on track for its mission of out-of-the-ecliptic exploration.

In addition to the grounding of the Shuttle fleet, the January 28 Challenger accident precipitated a general reassessment of safety issues, and, as a result, in June 1986 the Centaur G-prime rocket was cancelled for use as an upper stage for Shuttle. These two events left both the Ulysses and Galileo projects temporarily bereft of their upper and lower stages.

Meeks said that after the Centaur decision NASA Headquarters established a committee to select a launch vehicle and, in consultation with ESA, a launch date. The project supported this selection effort by supplying mission-design options and analysis. The result was the assignment of a three-stage combination for Ulysses: Shuttle, Inertial Upper Stage (IUS), and, on top, a Payload Assist Module (PAM-S).

After meetings between ESA and NASA representatives in Paris in January 1987, with two follow-on meetings at NASA Headquarters, it was announced jointly by both agencies in April that Ulysses would be launched in October of 1990 and Galileo in October of 1989. The rationale for the launch-date decision is that even with the earlier launch date Galileo will not begin to return data from its prime mission until approximately one year after Ulysses.

The primary scientific objectives of the Ulysses mission cover a broad range of solar physics: the properties of the solar corona and solar wind, the Sun/wind interface, the heliospheric magnetic field, solar (and nonsolar) cosmic rays, solar radio bursts and plasma waves, and interplanetary neutral gas and dust.

These phenomena will be characterised as a function of solar latitude. The uniqueness of Ulysses lies not in the closeness of its approach to the Sun but rather in its exploration of the previously untraveled regions above the solar poles: the high solar latitudes. The method of attaining high solar latitudes is, paradoxically, to proceed at first away from the Sun, toward the planet Jupiter. The Jovian gravity is employed to fling the spacecraft out of the plane of the planets and into an orbit that will eventually carry it over both the north and south poles of the Sun.

Some of the secondary scientific objectives of the Ulysses mission relate to the Jovian traverse: interplanetary physics investigations and measurement of the planet's magnetosphere during Jupiter flyby. A search for gravity waves and determination of the direction of cosmic gamma-ray bursts are also included among the secondary objectives.

The mission duration is approximately five years, extending from a launch some-

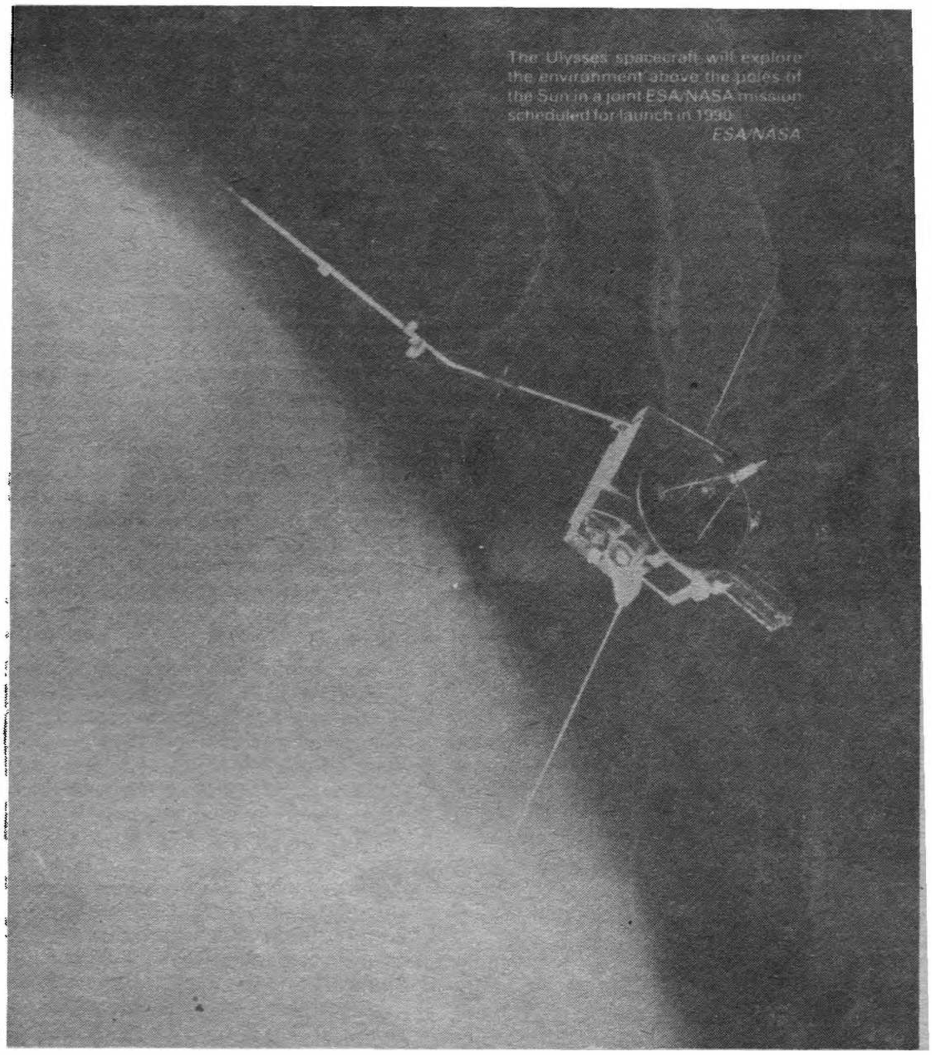
eparations

time in the period October 5 through October 24, 1990 (the "Jupiter window") until after the second polar passage, toward the end of 1995. In between these boundary markers, the mission timetable includes several periods of high activity. The first extends for about 50 days after launch while the spacecraft is checked out and the instruments turned on. Another period of high activity covers the time, in August 1991, when the spacecraft lies close to the Sun on the celestial sphere (solar conjunction), allowing analysis of the solar corona by the effect it has on radio waves sent from the spacecraft to Earth.

Jupiter flyby, in February 1992, constitutes a period of high activity as do the high-solar-latitude passes: May 31, 1994 to October 6, 1994 (south polar region) and May 30, 1995 to September 16, 1995 (north polar region). High solar latitude means, for Ulysses investigations, regions more distant than 70 degrees from the solar equator. At maximum latitude, the spacecraft will lie about 2.3 astronomical units from the Sun (one astronomical unit is the distance from Sun to Earth).

The 370 kg Ulysses spacecraft is supplied by ESA and has been built by a European consortium with Dornier Systems (Friedrichshafen, Federal Republic of Germany) as prime contractor. A second Ulysses spacecraft was to have been built by NASA, but this vehicle was cancelled in 1981 for budget reasons.

The spacecraft is spin stabilised, which is a favored method for fields-and-particles oriented missions. This mode of attitude stabilisation allows sampling of the environment from many directions on a continual basis. Three-axis stabilised spacecraft (using the Sun and a star for reference to hold the spacecraft stable), such as Voyager, are superior for remote-sensing applications. The Galileo spacecraft utilises both modes; fields-and-particles experiments are located on a spinning portion, while a scan platform with remote-sensing instruments, such as a camera, is included in a despun portion. The design for the proposed Comet Rendezvous Asteroid Flyby (CRAF) spacecraft represents another method of meeting the needs of fields-and-particles experiments; the remote-sensing instruments are located on a (high precision) scan platform on this three-axis-stabilised vehicle, while the fields-and-particles instruments have a separate (low precision) scan platform devoted to their directional needs.



The Ulysses spacecraft will explore the environment above the poles of the Sun in a joint ESA/NASA mission scheduled for launch in 1990.
ESA/NASA

Ulysses science investigations.

INVESTIGATION	PRINCIPAL INVESTIGATOR	ORGANIZATION
MAGNETIC FIELD MEASUREMENTS	A. BALOGH	IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY ENGLAND
PLASMA SPECTROMETER	S. J BAME	LOS ALAMOS NATIONAL LABORATORY
SOLAR-WIND ION COMPOSITION	G GLOECKLER J GEISS	UNIVERSITY OF MARYLAND UNIVERSITY OF BERN, SWITZERLAND
COSMIC RAY AND SOLAR CHARGED PARTICLE	J A. SIMPSON	UNIVERSITY OF CHICAGO
LOW ENERGY CHARGED PARTICLE	L.J LANZEROTTI	BELL LABORATORIES
RADIO AND PLASMA WAVE EXPERIMENT	R G STONE	GODDARD SPACE FLIGHT CENTER
MEDIUM ENERGY ISOTOPIC PARTICLE DETECTION	E. KEPPLER	MAX-PLANCK INSTITUT, FEDERAL REPUBLIC OF GERMANY
SOLAR-FLARE X-RAYS AND COSMIC GAMMA RAY BURST EXPERIMENT	K C HURLEY M SOMMER	CENTRE D'ETUDE SPATIALE, FRANCE MAX-PLANCK-INSTITUT, FEDERAL REPUBLIC OF GERMANY
COSMIC DUST EXPERIMENT	E GRUN	MAX-PLANCK-INSTITUT, FEDERAL REPUBLIC OF GERMANY
RADIO SCIENCE	H VOLLAND	UNIVERSITY OF BONN, FEDERAL REPUBLIC OF GERMANY
GRAVITATIONAL WAVE	B BERTOTTI	UNIVERSITY OF PAVIA, ITALY

Data are returned continually throughout the mission – this is a scientific requirement in order to provide context and calibration for the new explorations at high solar latitudes. They will be returned in real time and from playback of the onboard tape recorder. Data can be sent at rates between 128 and 8192 bits per second with 1024 bits per second prime for real-time data and 512 bits per second for playback data.

The 1.65m high-gain antenna utilises a 20-watt transmitter (X-band) for downlink (plus a 5-watt S-band transmitter) and receives commands from the ground at S-band.

Electrical power will be supplied by heat conversion through a Radioisotope Thermoelectric Generator (RTG) at a level of 285 watts for initial operations. Through natural decay of the RTG, the electrical power output is expected to decline at the rate of approximately six watts per year.

Meeks said that the launch delay of over four years has presented problems in managing hardware and people resources.

The ESA Spacecraft is currently in storage at Dornier Systems and will remain there until late 1988. Upon removal from storage, the spacecraft will be integrated with its complement of instruments (most of the instruments are now being stored at the home institutions of the Principal Investigators). Shipment to the Kennedy Space Center of the instrumented spacecraft is scheduled for May 1990.

After a 1987 launch was ruled out, the project staffed down to a level that was just sufficient to retain a corporate memory and to conduct launch-vehicle integration, mission redesign, and management functions.

Training new people for mission operations will begin for the JPL support team in April 1989, with testing of the ground data system to commence in October 1989. The first ESA personnel are scheduled to arrive in January 1990, with the entire contingent in place by March 1990. Peter Beech of the UK is the Mission Operations Manager, and Donald Meyer of JPL is his deputy.

Meeks, who has spent nine years on Ulysses, characterises this international project as being imbued with good team spirit based upon mutual respect between the two project offices

BUSINESS ARENA

DBS to Begin in Europe

by Theo Pirard

Eurosatellite GmbH of Munich has been looking for some time to the successful launch of the German TV-Sat 1 to demonstrate the high quality of TV transmissions from a satellite directly to viewers. On November 21, the spacecraft was placed in geostationary orbit by an Ariane 2 (V20) but subsequently one of its two solar panels failed to open, effectively reducing its capacity from four high-power transponders to two. After three months in orbit television broadcasting is scheduled to become operational and there is every hope that a new era of TV viewing will begin for Europe in spite of the reduced power.

TV-Sat 1 is the first of five spacecraft developed and manufactured by Eurosatellite. The others are: TDF-1 (to be launched in April or May 1988), Tele-X (end 1988), TDF-2 (autumn 1989) and TV-Sat 2 (early 1990, but the Bundespost is negotiating with Martin Marietta for a Titan III launch during 1989).

Jean-Pierre Baudry, Managing Director of Eurosatellite, states: "The advantages of TV-Sat and TDF-1 will expand rapidly after the first DBS transmissions. With their advent, the technology of communications satellites to broadcast TV programmes will appear very poor and obsolete!"

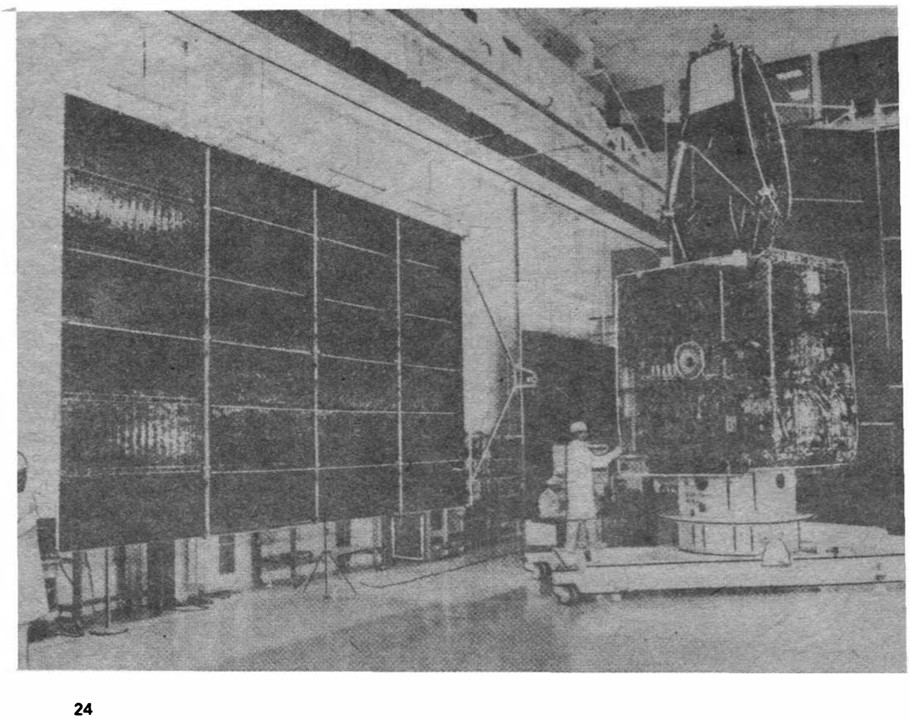
The first advantage of DBS will be the high quality of the TV signals. Individual reception will be possible from TV-Sat in Germany with a 35-40 cm diameter antenna; France (Paris) with a 50 cm diameter antenna; and in Italy (Rome), the United Kingdom (London), Sweden (Stockholm) and Poland (Warsaw) with a 70 cm diameter antenna. For Spain (Madrid), Ireland (Dublin), Tunisia, Greece, USSR (Moscow), a 1.5 – 2 m diameter antenna will be required.

The second advantage will be the high power of the TV broadcasts which, combined with the bandwidth, will permit and promote the development of HDTV (High Definition TV) transmissions with the D2-MAC Package. This new standard will replace the French SECAM and the German PAL.

Eurosatellite is actively working on studies for two other DBS projects in Europe: these are the Swedish Notelsat project to follow the Tele-X satellite during the 1990's and the Swiss Helvesat project which, according to a Swiss PTT official, is progressing "slowly".

In 1988, the launch of TDF-1 will be followed by the Luxembourg Astra 1 (during the autumn). Up to 24 new channels are expected to be available to TV viewers in Europe by the end of 1988: four with TV-Sat 1 (if it becomes completely operational), four with TDF-1 (if not delayed because of the solar panel problem with TV-Sat 1) and 16 with Astra 1 (if its transponder marketing obtains the expected success).

French DBS satellite TD F-1 is prepared for launch later this year in the clean rooms at Aerospatiale in Cannes *Aerospatiale*



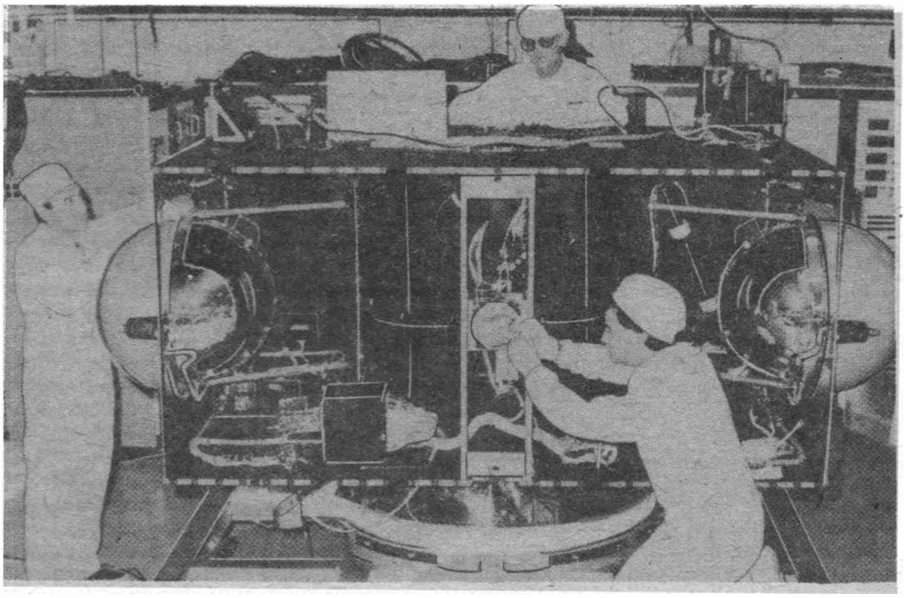
By the end of 1987 Societe Europeanne des Satellites (SES) was due to announce its first selection of TV broadcasters for Astra 1. The purchase of the Astra 2 satellite will hopefully be made during the first quarter of 1988, when all 16 transponders of Astra 1 should have found broadcasters for European TV programmes.

The MAC (Multiplex Analog Components) system is proposed for satellite TV broadcasts to achieve a high-quality picture with several sound channels. It opens the way to Hi-Fi television in the early 1990's and to HDTV channels. For HDTV broadcasts, MAC has to compete with Japanese MUSE, which is supported by American broadcasters. However, in the USA, MAC appears to be favoured by cable operators.

The Bundespost has decided to broadcast DBS channels with TV-Sat 1 using the D2-MAC TV transmission system, even if only a limited number of microchips will be available from the German company ITT Intermetal during the first months of 1988. First D2-MAC microchips, which are particularly complicated to produce, will initially be available for cable networks in German speaking countries (Germany, Austria and Switzerland). Telediffusion de France will also use D2-MAC for its DBS broadcasts with TDF-1. D2-MAC should therefore become operational in 1988.

The British D-MAC, which offers twice the number of channels as D2-MAC will be used by BSB (British Satellite Broadcasting) for DBS in the United Kingdom and by Tele-X for DBS in Scandinavian countries during 1989. The main advantage of the British D-MAC is that it is compatible for TV reception with D2-MAC signals whereas the reverse is not the case. The D-MAC microchip is developed and produced by an industrial consortium consisting of Nordic, Plessey and Mullard/Philips which is proposing a multistandard microchip for the reception of both D-MAC and D2-MAC.

This explains why SES is looking at the D2-MAC for the Astra system. The SES decision will be taken soon, hopefully with the anouncement of the first Astra 1 channels. The use of D2-MAC presents many advantages for SES. TV recieve only (TVRO) terminals, equipped with the Nordic/Plessey/Mullard microchip will receive also D2-MAC broadcasts together with the D-MAC signals. Since the beginning, SES has been conscious that Europe will replace its PAL/SECAM partition by D2-MAC/D-MAC and SES support for the French-German D2-MAC will give the French electronics industry an opportunity to enter the British TV market. SES's Astra system is promoting stations with three microchips: the first and most complex is to receive the D2-MAC signals (with D-MAC); the second is to allow decoding for pay-TV broadcasts; and the third is to achieve addressability for the TVRO terminals in order to receive pay-per-view TV channels.


The Astra-1 satellite during construction in the RCA workshops.

Developing Countries to Build More ComSats

Brazilian Embratel plans launch of the third Brazilsat for 1992. Pedro Jorge Castelo Branco, President of Embratel, is looking for the addition on Brazilsat III of a Ku-band payload. The first two Brazilsats, now in orbit and launched by Ariane 3 vehicles, are operating with success in the C-band frequencies.

Brazilsat I, located at 65°W, is functioning with 18 C-band transponders out of the 24 available: six for TV broadcasts (Globo, SBT, Bandeirtantes, programming, TV Executiva, TV credenciada), two for military links, 10 for general traffic. Brazilsat II, positioned at 70°W, is considered an in-orbit spare, but is used for specific telephony and TV links, and occasionally to reinforce Brazilstat I. Embratel is negotiating with Bolivia, Ecuador, Peru, Argentina, Colombia and Venezuela the sale of Brazilsat II transponders, each on offer for $4.8 million. According to Castelo Branco, only four of the 24 C-band transponders will be offered for sale.

Brazilsat III, carrying a payload divided between C-band and Ku-band transponders will be placed at 61°W. Brazilsat I and II spacecraft, being Ariane launched are guaranteed for respectively nine and 11 years; with the third satellite, the Brazilian communications satellite system will be operational until the mid-1990's.

Arabsat organisation is using two geosynchronous satellites (at 19°E and 26°E) while a standby satellite is being kept on the ground; each satellite has 25 C-band repeaters and one S-band repeater (for community television).

Mr. Abdelkader Sairi, who has been Director General of Arabsat since May 1986 and belongs to the Algerian PTT administration says that almost 20 of the 22 Arab member countries benefit from the services provided by Arabsat satellites and most of them rely heavily on the Arabsat system for inter-regional communications.

"The need is already being felt to ensure service continuity after 1991, when the useful life of the present first-generation satellites will come to an end, and preliminary arrangements are being made for launching and positioning second generation satellites in 1992," he said. During 1988, the RFP for second-generation Arabsat spacecraft will be prepared.

Indian Department of Space has plans to develop indigenously the second generation Insat spacecraft. In April 1985, the government of India approved the Insat-II Test Spacecraft Project which envisages design, development, test and qualification of two Insat-II spacecraft. While no operational dependence is planned on the first Insat-II Test spacecraft, both Insat-II satellites are expected to see operational service and play an important role in the transition from the Insat-I to the Insat-II space segment.

In 1988, ISRO (Indian Space Research Organisation) will select the payload for each Insat-II Test spacecraft and establish launch agreements to place them in geosynchronous orbit for the early 1990's. Ariane and Delta vehicles – selected to launch Insat-I spacecraft – will compete for the launch contracts with the Soviet Proton and eventually the Japanese or Chinese launchers.

ISRO plans to launch the operational Insat-II spacecraft for the mid-1990's with the Indian GSLV (Geosynchronous Satellite Launch Vehicle) which is now in the design phase.

Indonesian Permutel will launch the refurbished Palapa B2R in 1990 with a McDonnell Douglas Delta – this launch will keep the Palapa B system active until the second half of the 1990's.

The need for Palapa C generation spacecraft will appear in 1995 and the French Satel Conseil is preparing the RFP for Palapa C spacecraft which will use both C-band and Ku-band frequencies. Contracts for Palapa C will be placed in 1989 or 1990 to achieve a first launch during 1993/94.

Israel Satellite Corporation will launch two Amos satellites with Ku-band capacity: Amos 1 in late 1992 and Amos 2 in 1993. Each satellite, located at 15°E, which is near one Arabsat spacecraft, will offer eight transponders functioning with 20 W output to cover not only Israel but the Middle East and the Mediterranean (and the southern countries of Europe together with North African countries).

Developed and manufactured by Israel Aircraft Industries, the Amos spacecraft will take form with foreign assistance, maybe from European industry. It will be very similar in performance to the ECS/Eutelsat I spacecraft. The Israel Satellite Corporation – of which the General Satellite Corporation of UK and IAI are the main shareholders – plans to use Ariane launch services.

CORRESPONDENCE

Shuttle Liquid Fuelled Boosters

Sir, The idea of liquid rocket boosters for the US space shuttle (***Spaceflight***, November 1987, p.380) is not of recent date. There were studies in the late 1970's, as described in the NASA fact sheet on Shuttle Derived Vehicles (March 1980). The Marshall Space Flight Center had even awarded contracts to two companies to study concepts for such vehicles. One of the two was the same as recently selected to (again) study LRB's: Martin Marietta. It will be interesting to compare the results of this new study with the expectations NASA had in the seven year old fact sheet, which – in short – were as follows:

- A 50 per cent increase in shuttle lift capability (enabling it to carry aloft 35,000 pounds more cargo).
- Lower costs for checking out and loading the rockets with fuel.
- The LRB's are fuelled at the launch site, while the SRB's are filled with their solid fuel at Morton Thiokol's plant in Utah from where they are transported to Cape Canaveral, with – consequently – the chance of "cracks" in the fuel.
- Combined with a "side-mount" cannister, LRB's could yield a lift capability of 165,000 pounds, more than two times the current shuttle capacity;
- Reusability by using parachutes (as done with the SRB's) or in a winged configuration.

Personally I really would like to see the shuttle's non-controllable SRB's replaced by controllable LRB's, as it is very clear that the latter are much safer, and I am certain there are shuttle astronauts who share my view.

In conclusion I would like to say: keep up the good work!

ING. TON van ROOIJ
Eindhoven, The Netherlands

Spaceplanes Pose Legal Problem

Sir, Virtually all launches and controlled re-entries of spacecraft to date have traversed the airspace of the launching state or airspace above international waters. This practice has effectively postponed the resolution of tricky questions about the legal rights and liabilities of a government or other agency which sends spacecraft in powered or unpowered flight through the airspace of a foreign state.

The general assumption has been that while a spacecraft is passing through the Earth's atmosphere, whether or not it relies upon aerodynamic forces to sustain it in flight, it is subject to air law like any other aircraft.

But how will this work out in practice with spaceplanes operating in a region crowded with sovereignties and divided between rival alignments and alliances, such as Europe?

This problem is most acute in the case of the West German Sänger proposal, as it is presently formulated. The manned ascent and descent trajectories may perhaps be readily assimilated under existing air law and traffic regulations. However, the ascent trajectories will pass through the airspace of countries in northern Africa (possibly) and of others in the western half of Europe (definitely), not all of which are members or affiliates of the EC or ESA – particularly if airports in the centre of Europe, such as West Germany or the Netherlands, are ever used. The descent trajectories may raise questions about the relative manoeuvrability and fuel safety margins of a descending Horus, in comparison with those of the average jumbo.

The descent trajectories for the reusable lower stage from inclined or equatorial insertions are likely to be far more problematic. An unmanned (as far as one can gather) aircraft weighting something under 200 tonnes depending on the amount of fuel still on board, and decelerating from Mach 7, is not something governments and public opinion from Iceland to the Soviet Union are likely to endorse quickly and (equally important) unanimously. How many countries in the region will have landing facilities and accident teams which they would feel confident could handle any emergency arising? What sort of insurance would MBB be required to carry, and what would that do to the costs of the orbital tourism and other services they propose to inaugurate?

Hermes and Hotol are obviously faced with this sort of legal and acceptability problem to a much lower degree, as long as they stick to launching over water. However, international arrangements for such spacecraft to re-enter to major airports might also be somewhat less than straightforward.

Have MBB or the West German government made any suggestions or commissioned any studies, so far, about how to cope with this neglected aspect of "third generation space transportation"?

RIP BULKELEY
Oxford, England

ESA Should Consider Teledyne Spaceplane

Sir, Could the Teledyne Spaceplane concept of a totally reusable vehicle incorporating proven technology ***Spaceflight***, December 1987) be the ideal project for the European Space Agency to undertake? The idea seems to embody the major requirements for which member states have been lobbying.

If the concept is found to be workable it could be commercially viable as it is a totally reusable unmanned freighter and built of proven hardware which would lessen the doubts as to its feasibility for economists, engineers and member states alike. Future development of the vehicle design could include manned space flight and the project would be seen as a step forward in the European space programme.

I suppose there will be much criticism of the concept, but to embark on the development of a reusable Space Transportation System is the way forward and this system seems to minimise the main risks of development and operation which is required by some member states.

Totally reusable Space Transportation Systems are the future and now is the time to begin such a project.

DAVID W. GARBUTT
Lincoln, England

The Road to Human Survival

Sir, Mr. Roger White asserts quite rightly that the journey into space is the road to human survival (***Spaceflight***, November 1987. p.368). He concludes his letter by declaring that there are only two alternatives facing Mankind. As the Earth is dying anyway, we must either "go up . . . or go down".

I do not know whether he means to imply that *because* Earth is dying we must now concentrate all our efforts into the race to escape, and ignore what is happening to our home planet, but there is a real danger that his words will be interpreted in this way.

It is an attitude that has often been encouraged, and it stems from the real fear that Man will render himself extinct before he is able to climb up the next evolutionary rung. However, I believe it is an attitude which is to be deplored.

Firstly, many people at present alive – including space-faring people – will need to retain strong emotional ties with Earth.

They will fiercely oppose the extreme exploitation of the ecosystem which the "Space Ark" approach to survival requires to take itself seriously. More practically, in the construction of a human space civilisation it will be necessary for Earth to remain the Mother Support System.

Numerous errors will be made during the colonisation of space, and a permanent safe fall-back home will be needed

for possibly hundred of years to come. A careful regard for Earth environment therefore is crucial to Man's survival.

There is yet another reason. We are already travelling on a "Star Ark", and a far more human-suited, efficient and pleasurable one than any that could be artificially constructed. We are not threatened with cataclysmic destruction, a collision-of-the-worlds or an exploding Sun – the only scenarios which could possibly justify the creation of the Star Ark of romantic fantasy. Our threat comes from within, and it is one which will have to be overcome if we are to be *fit enough* to survive. It would be no survival at all simply to take our problems elsewhere, on to an artificial ark.

The moral attitude implicit in the Space Ark solution is also repugnant. Presumably most of humanity would be left to die whilst an elite few escaped? This comes dangerously close to gas chamber thinking.

I apologise to Mr. White if I belabour my point, especially if I am attributing to him meaning which he did not intend, but the whole moral conundrum posed by Space Ark theory has not been aired as much as it should.

I believe we should be fighting equally as hard to preserve the quality of Earth environment as we should be to achieve our evolutionary destiny in space. Further, if we are to sell the idea of space, I maintain that we have to reassure ordinary people. They are, after all, the people who in democratic nations determine spending. We should be in the business of impressing the public by exploiting space for the immense improvement it can make to the quality of human life here on Earth. The mining of the Moon and asteroids, would greatly reduce the effects of pollution and stimulate a hugh upswing in global economy with the occurrence of trade between Earth One (down here) and Earth Two (up there).

The discovery of space cannot be compared with the discovery, say, of America, nor its colonisation with that of India and Africa by Europeans. It is a genuine evolutionary step, as hazardous as that taken by our amphibian antecedents when the move was made from sea to land. We are in an equivalent "amphibious" mode, neither wholly land nor space orientated yet in need of both. Yes, the road to human survival is an imperative, and one that supercedes the survival of the individual, but to regard space as an escape route is not the answer we should be seeking.

MICHAEL BUTTERWORTH
Cheshire, England

Space Physics

Sir, At present I am seconded from my teaching post as a Curriculum Development Officer for Physics and my main task is to write pupil and teacher material for one of the topics within Standard Grade Physics, Space Physics. I enclose a copy of the course unit with which I am involved.

ANDREW ALLARDYCE
Elgin Academy, Moray, UK

Space Education Award

Sir, I read with some pride your report in November ***Spaceflight*** that BIS Executive Secretary Mr. Leonard Carter received the 1987 Arthur C. Clarke Award at the Awards Banquet during the 1987 Annual SEDS (Students for the Exploration and Development of Space) conference.

The award is presented annually by SEDS to an organisation or individual in recognition of their contributions to space education.

It was upsetting to note, however, that you credited the conference as being held in Houston, Texas. The chapter that sponsored the conference, based at the University of Alabama in Huntsville, was formed only six months prior to the conference and has worked very hard to further the goals of SEDS and make a name for itself. The group is very proud to have hosted the National Conference at UAH after only six months of existence and should receive due recognition for this achievement.

Incidentally, the Houston chapter is hosting next year's conference and it looks like they will be doing a very good job. We look forward to seeing some BIS student members there.

Congratulations Mr. Carter, and keep up the good work.

BILL CARSWELL
Alabama, USA

Ed. *Our apologies for locating the 1987 meeting at the 1988 venue and full credit to the SEDS group at UAH for hosting the 1987 meeting so successfully.*

Space Education

Sir, Our "Space and Space Travel" module, which is part of the Leicestershire Modular Science Mode III GCSE, lasts eight weeks and was prepared by myself and Colin Gray, Head of Science. The course replaces CSE single sciences and its highest grade is equivalent to an 'old' O-level pass.

Assessment exercises are aimed at "process" based work rather than pure recall of facts which on the Post Module Tests amounts to only 20 per cent of the total mark. I hope that this information will be of some interest, at least from the point of view of how some schools are trying to bring space-related matters to the forefront of education.

W. CALVERT
Burleigh Community College
Thorpe Hill, Loughborough, UK

Aircraft Modification

Sir, While I was reviewing the October 1987 issue of ***Spaceflight*** the picture on page 59 caught my attention. It showed the original seven US astronauts in front of an F-102. It is, in fact, an F-106A, a highly modified version of the F-102. The F-106 was 700 mph faster than the F-102, its maximum speed being 1,525 mph.

I look forward to reading future issues of ***Spaceflight*** at the Hughes Aircraft Space and Communications Division Library.

JOHN R. CHEVEDDEN
California, USA

Saturn V Launch Puzzle

Sir, The recent showing of the television mini-series "Space" (specifically the scene of an Apollo lift-off) has prompted me to write in the hope that you or another member of the Society can answer a question which has been puzzling me for some time.

During the early phase of a Saturn V launch, the CAPCOM would periodically call up to the spacecraft "One-Bravo...", "One Charlie...", "One-Delta...", etc. I understand that these terms refer to various launch escape modes, but I have never seen any detailed explanation of their exact meaning and I would be grateful if you could help me in this matter.

GORDON DAVIE
Edinburgh, Scotland

Ed. *Mitchell R. Sharpe of Huntsville, Alabama has discussed Gordon Davie's query with the Johnson Space Center Houston for us and according to them "CAPCOM and the flight crew during Apollo missions apparently lapsed into informal communications procedure". This could explain the absence of any record of the meaning of the terms used.*

CORRESPONDENCE

Soviets Use 'Space' Medicine

Sir, It is a well-known fact that over the past years, the Soviet Union had been active in the field of producing medicines in the zero-g environment. Recent examples of this research were reported in the September issue of ***Spaceflight,*** which in fact prompted me to write this letter.

One regularly reads and hears of Soviet medicine production in space, but on the other hand, one seldom learns whether such products can be or are already used on Earth. So I wrote to Star City, addressed to Leonid Kizim, since he commanded the 237-day Salyut 7 mission in 1984 during which a medicine for bone decalcination was made. Last spring I received a reply and it turned out that this medicine can indeed be used to treat Soviet people who suffer the mentioned ailment (old and paralyzed people).

Another question of mine, on a totally different subject, was whether the Salyut 7 and Mir station would be docked some day, as there had been rumours in that direction. Well, there were no plans for this, I was told in the letter.

ING. TON van ROOIJ
Eindhoven, The Netherlands

Vostok Landings

Sir, The photograph produced by Lucien van den Abeelen (Spaceflight, December 1987 p. 431) is, indeed, part of a film sequence shot after Valentina Tereshkova's return to Earth. However, as other photos in the sequence clearly show, it was taken some time after the landing – the 'cosmonette' is no longer wearing her helmet or pressure suit. Presumably, the ejection seat has been brought to the scene from its nearby landing site for the purposes of the film makers.

The Soviets have made no secret of the fact that the Vostok cosmonauts did not land inside the spacecraft, but ejected at an altitude of about 21,000 ft. As Konstantin Feoktistov commented: "The descent module descended at a speed of 10-11 m/sec. This landing velocity resulted in shock G-forces on the hull of the order of 100 g's, which would be absolutely unacceptable for the cosmonaut inside.... it was decided to eject the cosmonaut before the module landed". This applied to all Vostok flights, including Tereshkova's, as press reports of the time made clear.

Korolev himself confirmed that Voskhod I was the first Soviet craft with a soft-landing system. When asked by a Tass correspondent about the difference between the two craft, the Chief Designer replied: "Above all, the fact that the craft and crew came down together, not separately".

PETER R. BOND
Sheffield, England

Cautious Approach to Mir Build-up

Sir, Reports from the 38th IAF Congress appear to contradict the agenda Philipp van Stratum had heard from cosmonaut Jean Loup Chrétien regarding the expansion of the Mir orbital complex (***Spaceflight***, November 1987, p.368).

Vladimir Kotelnikov, chairman of the Intercosmos Council, and Valeri Ryumin, director for Soviet manned spaceflight are now quoted as saying that the Mir station would be completed "without any hurry", the most important factors in the further planning being the safety needs of the cosmonauts and the economy of the whole enterprise. Therefore the next science module will not be launched in late 1987 as earlier reports had indicated but in 1988 or even in 1989. Full use of all six docking ports will also not be made for "several years" [1]. As the Soviet-French mission has been set for November 1988 [2] it is very likely that the French visitor will experience the Mir complex in a quite early state of expansion.

Regarding Lee Cadwell's thoughts about the future use of Mir's docking ports [3], I would like to draw your attention to a recent note from Moscow: "Soviet drawings of Mir in its fully operational configuration show two large specialised modules docked to the upper and lower ports of the ball-shaped docking-unit, giving the station an overall length of 27 metres (89 ft.) in this axis. The drawings show smaller modules mated to the two side ports of the docking unit [4]".

I do not believe there will be a need for two Soyuz TM's plus one Progress being docked to Mir at the same time. When the 'replacement' of Laveikin by Alexandrov was announced in late July 1987, Flight director Viktor Blagov declared that this partial crew exchange took place under an "already established concept": during future Soyuz flights one or more of the cosmonauts would be replaced continuously, in order to keep Mir manned all the time [5]. When doing so, it would be no problem to increase the crew on board step-wise if that would be needed.

DANIEL FISCHER
Königswinter, West Germany

References

1. "Modulstation, Mondbasis und Marsflug", *Wochenpost* 42/1987, p 8
2. "Zweiter sowjetisch-französischer Raumflug", *Das Volk*, Oct 22, 1987
3. *Spaceflight*, November 1987, p 369
4. "Soviets use new Gyros to Stabilize Mir Station", *Aviation Week & Space Technology*, November 2, 1987, p 79-80.
5. "Erfolgreiche Arbiet des...Raumfahrerteams", *Das Volk*, July 25, 1987

Drawings of Soviet Activities

Sir, Would it be possible to add regularly to all drawings in ***Spaceflight*** of Soviet space concepts, what the source of that drawing is? Though the wealth of material presented in your magazine is highly welcome, it is sometimes difficult to make use of it: one always has to ask oneself, is it official from Moscow, does it come from the Pentagon, or has it been put together by an independent western expert? If the latter is the case, one still wonders whether the information used was scientific speculation or based on first-hand sources.

When it comes to the Soviet shuttle, the situation is especially frustrating. To my knowledge, almost all drawings in circulation were adapted from the Soviet Military Power annual books. Last April after the Soviet Union officially announced that there would be a shuttle, several drawings (highly detailed) were published in the eastern media. At first I believed that they were official material supplied by the actual designers of Energia and the shuttle, but I am not sure after the leading East German newspaper Neues Deutschland reprinted the Soviet shuttle drawing from ***Spaceflight*** November 1987, p.379 in its October 31, issue!

The same applies to almost any drawing of Soviet activities: giving references for anything non-photographic would be enormously helpful.

DANIEL FISCHER
Königswinter, West Germany

Ed. *The inclusion of references to original sources of material is a well-recognised feature of* ***Spaceflight*** *articles. In the case of Soviet spacecraft and launch vehicles we endeavour to provide the most accurate and up-to-date illustrations that circumstances allow. The new Soviet policy of 'Openness' is a benefit to this situation. Photographs of Energia, the Kvant module and other items have been released and models of them have been on public display.*

Tenth Planet Mystery

Sir, Dr. Anderson's theory on Planet X (***Spaceflight***, September 1987, p.323) is an ingenious attempt to reconcile factual but controversial evidence for the existence of such a body.

The concept of an orbit with high inclination is not new,

neither is the suggestion of a highly eccentric one with a period of 700 to 1000 years.

In 1972 [1] Brady proposed a massive body (80 per cent of the mass of Jupiter) inclined at 60 degrees with retrograde motion. The proposed orbital parameters largely eliminated the residual of motion for Halley's comet.

Goldreich and Ward [2] pointed out that such a body could not exist without exerting an influence on the plane of motion of the Solar System. In particular they suggested that the major axis of this plane would drift in an observable manner. No such drift has been noted. This, combined with other evidence has largely discredited Brady's solution.

The same dynamic argument applies to Dr. Anderson's proposal with the basic motions reversed, i.e. the orbital plane of the Solar System hardly drifts, but the orbit of Planet X will slowly change with time. It is difficult to exactly quantify the total time required for each cycle of change, but 40-50 million years could be a first level estimate. This means that twice during each cycle, i.e. every 25 million years, Planet X will lie in the plane of the Solar System and therefore exert a maximum effect on the Oort cometary ring.

Such a suggestion reconciles the 25 million year cataclysmic cycle of cometary impacts without having to resort to distant red, brown or black dwarf companions of the Sun – the hypothersised "Nemesis".

Lawton [3] suggested a highly eccentric orbit for Planet X lying in the plane of the ecliptic and with a period of 495 years, (later revised to 745 years in unpublished calculations). Anderson's figures of 700-1000 years can be taken as bracketted estimates for a period that *must* resonate at some harmonic multiple of the orbital periods of the outer planets. In Ref. 3, I chose 495 years as being the simplest harmonic period, but 745 years gives a better fit to the observed data of the perturbation of of Neptune. There is little doubt that it *has* been perturbed in times past and as Pluto is far too small another more massive body is therefore probably responsible.

This is where Anderson's work is valuable, for Pioneers 10 and 11 can be regarded as miniature "asteroids" of very accurately known mass carrying very accurate measuring apparatus. Anderson is using these freely available facilities to measure any unknown perturbation fields. Voyagers 1 and 2 should be able to supply further correlating data for the mapping of any such anomalies.

Failure to find such anomalies must not be taken as proof of the non-existence of Planet X. In Ref. 3, I suggested that Planet X was presently heading for an aphelion of approximately 90 AU (later amended to 100 AU) and therefore could be extremely difficult to locate by any presently known means. As Pioneers 10 and 11 and Voyagers 1 and 2 have covered only one quarter to one third of this distance, it is hardly surprising that the results are so far negative.

I sincerely hope that Anderson and his colleagues will continue to be funded in what is essentially a very long term project lasting into the first quarter of the 21st century.

As one who "has faith" in the existence of Planet X, I wish him every success in his pioneering work.

A.T. LAWTON
Middx, UK

References
1 J L Brady "The Effect of a Transplutonian planet on Halley's Comet" Publications of the Astronomical Society of the Pacific, **84**, 314-322 (1972)
2 P Goldreich and W R Ward "The Case against Planet X", Publ Ast Soc Pac **84**, 737-42 (1972)
3 AT Lawton "The Many Shades of the Tenth Planet", ***Spaceflight***, **21**, 115-118 (1979)

Enlightenment Needed

Sir, Enclosed is my membership renewal for 1988, together with a small donation for the building fund. I have found ***Spaceflight*** most interesting since discovering the first issue on general sale by chance in September 1986.

The general attitude of the 'press' towards space research and exploration seems to mirror that of the Government; the latest pronouncements from the latter would have us believe that there is no future in space.

I remain hopeful that there will still be British contributions to be reported in the magazine, along with those from every other nation with more enlightened rulers.

IAN STRUGNELL
Essex, UK

Promoting Space

Sir, What is the Society doing about the assault on its belief in space flight being made by the Government?

Does the Society recognise the appalling weight of ignorance and indifference that must exist in this country concerning the motives and purposes of space flight if the Government can get away with such assault?

Has the Society given any thought to giving itself *a much louder voice?* I have not seen the Society so much as mentioned in connection with recent events. For how many more decades will the Society really speak only to the converted?

PAUL LISTER
Bath, England

Ed. *The questions put by Paul Lister are wrongly based on the supposition that Government negativeness related to Society inactivity. Any organisation whose aims are being thwarted by political decision or indecision can all too readily find itself unjustifiably "in the firing line".*

The Society has been battling against a lack of commitment by successive UK Governments to space since its earliest days and not entirely without success as a glance at its 1960, 1965 and 1972 Recommendations to Government bear witness.

In 1934, the Society drew the attention of the Government of the day to rocket motor developments that were then going on abroad only to receive a very negative ministerial reply showing a surprising lack of understanding in high places of the basics involved. By 1988, the terminology may have changed and the basics of space exploration may have developed considerably, but the need to instil them in high places remains and the Society is fulfilling that need to the maximum within its constraints of financial and other resources.

We would recommend to Paul Lister that he follows Mr. Barratt's example (see below) and writes to his MP.

Informing the Media

Sir, I would like to commend Mrs Valley Turner's remarks (Channel 4 "Comment", 7.50pm, November 24, 1987) about the lack of commitment and research funding, in particular with space research, which this Government, as with many before it (only more so!), is pursuing. She has finally made the point – albeit in only a small way (10 minutes) – that we, the BIS, appear to have failed to make to the media at large. Perhaps now the media may take up a more informed interest in this problem.

D.J. EARL
Plymouth, UK

Ed. *We would like to believe along with Mr. Earl that the media are about to take a greater interest in space. The long-standing inadequacy of media coverage of space, particularly by the British media, has been something that the BIS has worked constantly to reverse. The situation was highlighted by an editorial in the February 1985 issue of **Spaceflight** headed 'Where, Oh Where Have the Media Gone?'.*

Recently the BIS was host to 200 representatives of the

media including many TV networks, who received a mammoth infusion of information about current space events at its SPACE '87 Exhibition and accompanying IAF Congress at Brighton. In this and other ways the Society's promotion of informed media interest during the recent lack of Government commitment has been unsurpassed. At the same time, its role may not have been fully recognised, as Mr. Earl's letter would appear to indicate.

Protest to MP Over Government Stance

Sir, I am enclosing copies of the correspondence I have had recently with my Member of Parliament, Julian Critchley, about the United Kingdom government's attitude to Space research. I hope that they may be of some interest to you.

I cannot help feeling like a small voice crying in the wilderness but at least somebody has heard it. Perhaps if enough of us do speak out then even at this late stage, all may not be lost. Mr. Critchley, at any rate, has taken the trouble to present my protest to the seat of government and for this I feel we owe him many thanks.

A.M. BARRATT
Surrey, England

Ed. *Readers are urged to follow Mr. Barratt's example and protest to their MP about the UK Government's attitude to space in terms appropriate to their own interests and opinions. In this way one 'small voice' can soon become a 'thunderous roar' and provide a very effective addition to the Society's own actions. The response to Mr. Barratt's letter from John Butcher, Under Secretary of State for Information Technology, is reported on p.39. Mr. Barratt's letter was as follows:*

To: Julian Critchley, MP,
House of Commons, London,

I am writing to you as my Member of Parliament to protest most strongly at the Government's current attitude to Space research. I believe that this research is such an important activity, both to this country in particular and the world in general, that the recently reported decision of the Executive not to increase the funding for space is almost unbelievedly short sighted.

It is only fair to you to declare my interest in this matter, I have worked in the aerospace industry for virtually all of my working life and was for six years based at Woomera in South Australia helping to launch the Black Knight research rocket and the Black Arrow small satellite launcher, with which, as you may recall, Great Britain orbited its own satellite but then cancelled the project.

You may also remember that Great Britain had the basis of a very powerful launch vehicle in the Blue Streak-Black Arrow combination which was not proceeded with. This country, which has many times led the world in scientific and applied research, is in my view in serious danger of becoming an "also-ran" and I believe that the appalling tendency of the authorities towards the "market force" economy is leading us down a dreadful road towards mediocrity.

I ask you, therefore, to do all you can to impress upon the government the very real dangers of the path which they are treading and to campaign as strongly as possible for an increase in the funding for space research to at least that recommended by Roy Gibson, ex head of the British National Space Centre.

A matter of such importance as space cannot be left to "market-forces", particularly in view of the recent and continuing City debacle. It must be a National matter and accorded every reasonable resource from Government agencies, strongly led by such as the B.N.S.C. The current obsession with profits by the accountant-led management of many companies is no replacement for imaginative and strong government support.

With thanks for your attention and in the hope of your support,

I remain, Yours sincerely,

A.M. Barratt, BA, C.Eng., M.I.Mech.E., FBIS.

Congress Comments

Letters of appreciation to the Society following the IAF Congress and SPACE '87 Exhibition at Brighton continue to be received. To those previously published in the December issue of *Spaceflight* we now add a further selection to cover various other facets of the two events:

I would like to congratulate you and your hard-working team on the way in which you organised the IAF Congress at Brighton. Well done! I thoroughly enjoyed the whole meeting (apart from the storm), as did all my colleagues, and I have heard nothing but praise.

DAVE FEARN
Royal Aircraft Establishment
Farnborough, Hants

Many congratulations on your great efforts at Brighton.

DENNIS CUMMINGS
PETER ANSON
Marconi Space Systems

I certainly want to thank you for your wonderful hospitality at Brighton. I really enjoyed the Congress and thought it came off very well in spite of the weather problems.

ROBERT F. FREITAG
Virginia, USA

It was a great Congress, the right people were there; all the arrangements were fine.

MIREILLE GERARD
Corporate & International Programs
American Institute of Aeronautics and Astronautics

I would like to congratulate you on the excellent organisation of the Congress. The efforts of the BIS worked out very well!

ERNST FASAN
Neunkirchen, Austria

Let me congratulate you on a very successful conference in Brighton. Everyone enjoyed the reception at the Royal Pavilion and I should like to thank you personally for making all the detailed arrangements.

MICHAEL J. CHURCH
Pergamon Press

I congratulate you and all your BIS colleagues for the superbly organised Congress in Brighton. Please give my best wishes to all involved in the outstanding accomplishment. My only regret was to have read Mr Kenneth Clarke's remarks and to consider the consequences for the British space programme

FREDERICK I. ORDWAY III
Virginia, USA

APPEAL – Latest Report

In May 1987, the Society launched its £80,000 Building Appeal Fund for a much needed extension to its Headquarters The new building will be on two floors connecting with the Conference Room on the ground floor and the Library on the floor above.

Our thanks are recorded to the many contributors who, by November, had raised the fund total to £3353. Many members are supporting this Appeal as they send to the Society to renew their membership for 1988. Please take the opportunity at this time to send your contribution to the fund and keep the total climbing ever upwards.

Total: **£3353**

Your generous support will be gratefully received and acknowledged. Send to:
The Executive Secretary, The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ, England.

1988 Programme Shapes Up

The Society looks forward to 1988 with confidence after having just completed one of the most active years in its history. Not only is 1988 expected to see important developments in space with, hopefully, the re-introduction of US space shuttle launches, but the Society itself looks forward to moving from strength to strength with a programme of publications and activities that will further enhance its long-standing position in the world of space and astronautics.

For Britain, however, 1988 begins at a new space 'low' following the Government's failure to adopt a long-term space policy either by increasing its contribution to ESA or in any other clearly defined way.

The Society's role, therefore, assumes increased importance being needed more than ever to promote the right ideas and, eventually, alter the trend of events. It is not only in Britain that the Society offers an embodiment of space expertise and accomplishment but also overseas through its international membership, which brings influence and benefits to a whole range of Society activities.

In 1988, ***Spaceflight*** will continue to keep readers up-to-date with news of the latest events in space and with reports on recent space developments. Industrial and commercial considerations, which are increasingly influencing the direction of space programmes, will continue to feature prominently along with important related events involving space business interests. ***Spaceflight*** will be distributed monthly in 1988 with overseas copies again to be sent by air-speed mail.

The Society will continue to publish technical papers in ***JBIS*** for which several special issues are planned during 1988. The first of these will be devoted to 'NASA Space Science' and will contain so much excellent material that the January and February issues will be combined into a double-sized issue to take account of this. Despatch will be towards the end of January, slightly later that the normal date. The March issue will be devoted to 'Soviet Astronautics', which was the subject of a very well-received issue in 1987, so much so that requests for copies quickly exhausted available stocks.

Details of Society meetings for early 1988 appear below in 'Meetings Dairy' and include two all-day technical symposia at which, in accord with previous practice, luncheon will be provided inclusive with the registration fee. Detailed programmes for these meetings will be available in due course. As most members are not able to attend Society meetings without travel difficulties, the Society publishes both reports of them and many of the papers presented whenever practicable.

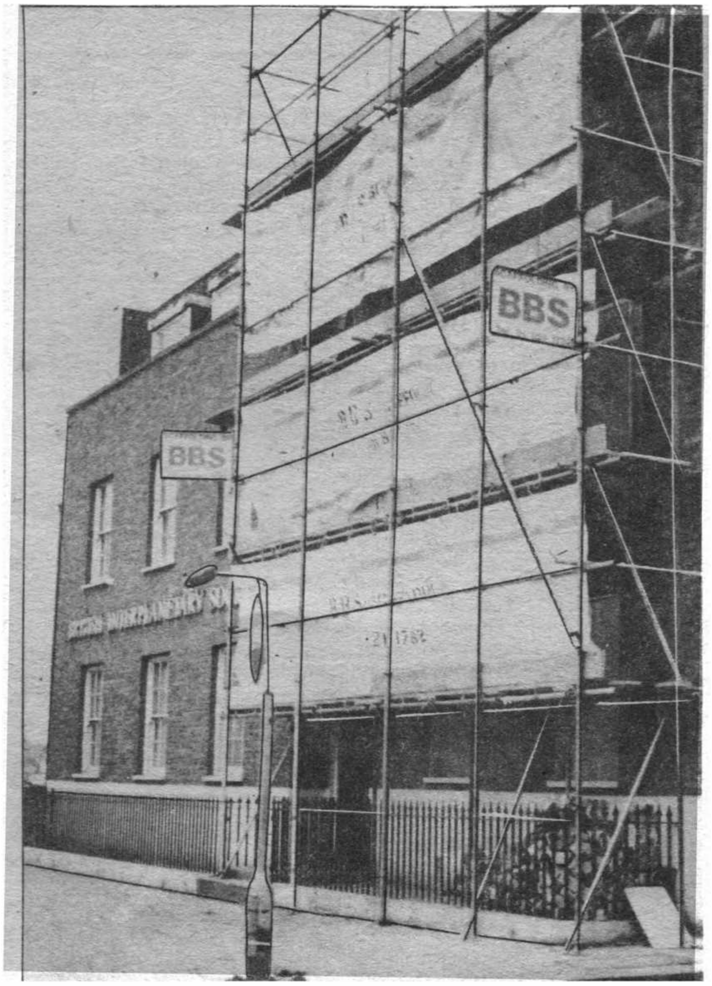
39th IAF Congress

The 39th Congress of the International Astronautical Federation will be held at Bangalore, India on October 8 to 15, 1988.

Members of the Society wishing to present papers should note that the Abstract deadline is March 1, 1988. Procedural details for submission of abstracts may be obtained from: The International Astronautical Federation, 3-5 Rue Mario-Nikis, 75015 Paris, France.

JBIS for 1988

JBIS, the Society's main technical journal, may be taken by members at a much reduced annual subscription rate of £22.00 (US$36.00) for 1988. The January/February special issue is devoted to 'NASA Space Science'. Orders for ***JBIS*** should be sent to the Society with remittance enclosed or may be placed on the 1988 Renewal Form which has been distributed to all members by mail.



Society HQ Under Repair

As reported in the last issue of *Spaceflight* considerable damage was caused to the roof and some of the upper rooms of the Society's premises by torrential rain following the hurricane-force storm that swept across London and SE England on October 15-16.

The urgent need for extensive roof repairs has provided an opportunity to put in hand long-standing plans for renovating that part of the property originally designated as No 29.

Four projects are involved (i) rebuilding the front wall of the uppermost two floors to overcome a long-standing structural weakness, (ii) extensive re-roofing together with the replacement of roof timbers and the addition of larger ducts for conducting rain-water away from the roof area, (iii) relining the walls of the basement rooms to prevent damp penetration and (iv) enlargement of the yard at the rear of the building to provide improved access.

It is item (ii) above which relates to the damage caused by the torrential rain. Item (iv) is a prerequiste to the building of the proposed new extension over a part of the yard which will be undertaken as soon as adequate funds are available to meet the costs involved. Donations to the Society's Building Appeal Fund are being earnestly sought to help meet the costs of the proposed new extension.

Last 120 Copies of Project Daedalus

Since its publication ten years ago the Society's report on Project Daedalus has received international attention far beyond what might have been foreseen.

The report examined the prospects of carrying out a simple interstellar mission using only current technology and reasonable extrapolations into the near future. The unique nature of the report and the serious attention that it gave to technical detail are probably the main reasons for the interest that it aroused.

The Society's stock of copies is now down to 120 and, as the report will not be reprinted, the last chance to obtain a copy of it is fast approaching.

Copies are available only from the Society and may be obtained at a price of £7 (US$12) each, inclusive of post and packing.

Obituaries

C. Stark Draper

We regret to record the death in July 1987 of C. Stark Draper, an Honorary Fellow of the Society since 1971.

Dr. Draper founded the Instrumentation Laboratory at MIT and was internationally recognised for outstanding pioneering contributions in the field of inertial guidance systems. He succeeded the late Frank Malina, who was also a Fellow of the Society, as President of the International Academy of Astronautics in 1963 and held this office for 20 years.

G.E. Pendray

We regret to report the death on September 5, 1987 of G. Edward Pendray, an early Fellow of the Society, who was elected a few months after the Society was formed in 1933. He was a pioneer rocket experimenter in the United States in the 1930's, being at one time President of the American Rocket Society.

Ed Pendray was also a pioneer of international cooperation and in 1934 was in communication with Mr. P.E. Cleator, the Society's President, concerning the setting up of an international rocket society, an idea which eventually came about in 1951 when the formal constitution of the International Astronautical Federation was adopted and ratified at the London Congress.

Writing in the October 1935 issue of the *Journal of the British Interplanetary Society* under the title 'Why Not Shoot Rockets?', he describes how the American Interplanetary Society (later renamed the American Rocket Society) transformed from a debating society into an engineering-based society with the successful launch of its first rocket in 1931.

"With a few inexpensive experiments", he said, "we 'sold' the rocket idea to men of high standing and influence, who previously thought the whole notion absurb". A cost breakdown of his society's first rocket experiment makes interesting reading, the rocket itself costing a total of $30.60 and an additional $18.80 going on launch costs.

A.C. Clarke Books Donated

The Society records its appreciation for the donation of a complete collection of the books written by Arthur C. Clarke. These were originally the property of the late Val Cleaver, a former Fellow and one-time President of the Society, who was also a long-standing friend of the author. Their personal relationship is signified by cryptic remarks which the author made in each book to Val Cleaver either about the book or Val's involvement or influence in its preparation.

Following Val Cleaver's death in 1977, the collection passed to his sister who subsequently gave them to Mr. F.W. Clarke, the author's brother. In writing to the Society about the collection, Fred Clarke says: "I consider it a particularly important collection and the safest home for it, where it will be of most use and interest, is in your Headquarters. If you consider it is suitable for your collection perhaps you would accept it with my best wishes."

Readers will recall that the Society is constantly seeking specialised or unusual items in its field of interest as donation to its Library. As well as books, items such as medallions, first-day covers and small space artifacts are of interest. Early books on astronomy, rockets and space are particularly desired. Readers in a position to assist the Library by augmenting its specialist collection are invited to discuss the matter (or write to) the Executive Secertary.

Winged-Horse Crest

The Society gratefully acknowledges the presentation to it by Dr. W.R. Maxwell, a Past-President of the Society, of a Royal Worcester gold-rimmed saucer dated 1876 which bears the crest of a winged horse, Pegasus, and the motto "Non Sufficient Orbis" (The world does not suffice). "Both crest and motto seemed appropriate to our Society", said Dr. Maxwell, "although they are those of the Bond family of the Isle of Purbeck, Dorset."

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

3 February 1988, 7-9 pm **Lecture**

ENCOUNTER WITH HALLEY'S COMET

Prof. J.A.M. McDonnell

Members only. Please apply for ticket, enclosing SAE, in good time.

5 March 1988, 10.30 am **Visit**

UNIVERSITY OF SURREY

A tour of the UoSAT Spacecraft Engineering Unit for BIS members. Further details from: Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose SAE. Numbers will be restricted so please apply in good time.

9 March, 1988, 7-9 pm **Lecture**

HOTOL – A SPACEPLANE FOR EUROPE

G.P. Wilson

Members only. Please apply for ticket, enclosing SAE, in good time

23 March 1988, 10-4.30 **Symposium**

HISTORY OF BLACK KNIGHT

An all-day Symposium. Refreshments will be provided and as numbers are limited early registration is advised.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

19 April 1988, 10-4.30 **Symposium**

DIRECT BROADCAST BY SATELLITE

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

High power direct broadcasting into individual homes could have great potential but, as with any investment in commercial space technology, the risks are high. Each European country is proposing its own national programme but a single satellite could cover all of Europe. Britain struggles to come to a decision on the future of DBS. Would cable or medium power TV satellite distribution be a better answer? A wide range of technical problems will be the subject of this one-day symposium.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

4 June 1988, 10-4.30 **Symposium**

SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

New Member Drive for 1988

January is the prime time of the year for new members to join the Society and we are looking for ways to bring Society membership to the attention of more and more people.

We appeal particularly to existing members to bring the work of the Society to the attention of colleagues and others and would suggest that there is probably no better way of doing this than by offering them the opportunity of seeing a copy of ***Spaceflight***. With this in mind, a copy of ***Spaceflight*** will be sent free of charge by the Society to any friend or colleague that you wish to nominate. Please write to the Society sending in their name and address.

1988 Membership Cards

Due to a change of scheduling arrangements, membership cards will not be included with the January issue of ***Spaceflight*** as in previous years. Instead they will be dispatched to members in late January with the February issue and care should be taken when discarding the envelope of that issue to ensure that the card has not been left inside.

Membership Card in Orbit

The Society has been pleased to accept the presentation to it of the 1985 membership card of Charles Walker, astronaut and Fellow of the Society. The item, which is the first BIS membership card to have been in orbit, is accompanied by a NASA Certificate of Authenticity and is now in the process of being framed for display purposes.

Mr. Walker was the first fare-paying passenger in space on STS 41D on August 30, 1984. The membership card was carried on his second mission, 51D, under the command of Col. Karol Bobko and beginning on April 12, 1985.

Honour for Founder of BIS

Mr. Philip E. Cleator (left), who founded the British Interplanetary Society in 1933, has been honoured by the American Institute of Aeronautics and Astronautics with the presentation of a Citation in recognition of his outstanding contributions to astronautics which led to the foundation of the BIS. The presentation was made by Larry Adams, President of the AIAA, during the History Session of the 38th IAF Congress at Brighton on October 16, 1987.

Report of 42nd AGM

The Society's 42nd Annual General Meeting was held in its Conference Room on September 19, 1987, with the President in the Chair.

The President opened the meeting with a review of the Society's affairs for 1986, full details of which have already been published in ***Spaceflight***, September 1987, pp. 335-339.

Introducing the Accounts, the Executive Secretary pointed out that the Society's income had been used to the full on current programmes, with nothing retained for future development. This was why further sources of income were urgently needed, hence the current appeal to raise £80,000 to provide extensions to the facilities for members in both the Conference Room and Library.

However, there was also urgent need to improve the entrance and general appearence of our HQ premises to make them much more attractive and to provide a much deeper sense of satisfaction to those members, many of whom had travelled long distances, who came to visit us.

Although the Society was identifying the need to seek additional income through its saleables and other services, this was less than adequate, hence the current appeal to members to provide gifts and donations to reach an £80,000 target quickly and thus enable this work to completed without delay.

Timing is important as the Library is growing rapidly and needs extra room and there were time limits imposed by Planning Permission which have to be met etc. It is therefore a matter of concern that the target sum be raised in the shortest possible period.

Auditors

The president reported that the current Auditors did not wish to continue and proposed that the meeting vest in the Council the power to fill the vacancy by the appointment of Auditors and fix their remuneration, with the matter coming up for renewal at future Annual General Meetings in the normal way. This was carried unanimously.

Special Resolution

The President proposed that Clause 42-B of the Articles of Association of the Society be amended to read as follows:

No person, whether a member of the Council retiring at the Annual General Meeting or not, shall be eligible for election or re-election to the Council unless:

(a) not later than the nomination deadline, there shall have been left at the registered office of the Society a notice of nomination in writing signed by two Corporate members and also notice in writing signed by the person nominated of his willingness to be elected; or

(b) after the nomination deadline, the Council shall have decided to nominate or to approve the nomination of a person with a view to ensuring a fair election.

In explanation, the Executive Secretary added that Clause (a) was exactly that already existing. Clause (b) was the new item which had been added on the recommendation of the Society's solicitors to take account of a situation where persons nominated had subsequently retired or were otherwise prevented from taking office after the expiry of the deadline, for, in that event, the list of nominees offered to the membership could be inadequate and/or might not fairly reflect the Society's interests in all disciplines relating to astronautics.

The change was intended as a matter of last resort and as a service to members to ensure that the best possible choice was presented to them. The Resolution was put to the vote and agreed unanimously.

Council Membership

The President reported that the four members of the Council due to retire had expressed themselves willing to stand for re-election and, additionally, a further nomination had been received. It was agreed that the election should be by postal ballot in accordance with Article 44, with the final date for receipt of ballot papers fixed at January 31, 1988.

General Discussion

The general discussion centred on events stemming from the problems of lack of national space funding, together with the international complications which had ensued, particularly those affecting ESA and NASA.

Observation was made that space expenditure was being treated by HM Government as just another area jostling for funds and was at a considerable disadvantage because it was unable to compete with other areas able to offer more rapid financial returns. It was also observed that money spent on research and development in the United Kingdom was now about the lowest of any ESA member.

The Executive Secretary responded that there was a fundamental need to get something done but this involved not only urging a well-thoughtout space programme and reasons in support, but also providing arguments as to why other areas should not be preferred.

EUROPEAN RENDEZVOUS

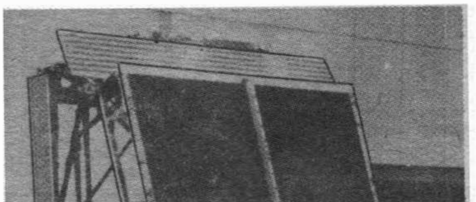
Europe Takes Aim – the 21st Century in its Sights

by Norman Longdon

There was an air of quiet jubilation when the European Ministers responsible for Space matters toasted the success of their meeting in The Hague on November 10, 1987. Coming together nearly three years after their meeting in Rome, which had fired the imagination of all interested in space, they now faced the hard reality of making decisions which would commit European governments to a much enlarged set of programmes for the peaceful use of space well into the 21st century.

That they were able to reach such a degree of accord speaks well for the consensus of opinion in most countries that space has an important role in the economic, technical and cultural cooperation in Europe.

Europe prepares for its own Earth observation programme – ESA's European Remote Sensing Satellite (ERS-1) during integration work. *ESA*



Twelve of the 13 ESA Member States were able to give their complete agreement to the Resolution which sets in motion the next phase of the European Space Agency's programmes. There were strong voices of hope that the United Kingdom, which had not felt that it could endorse several aspects of the Resolution, would be able to review its position during the coming months. The other Member States remembered the part which the UK had played in the build-up of the European Space venture, and made it clear that the UK still had a major role in the future ESA programmes.

The Objectives

The precise nature of the objectives and planning for the coming decade and a half is interesting. Coherence, completeness and balance are the key words and they will govern the thinking at all levels as the programmes and projects progress to fruition.

Coherence is to be achieved between the different programme sectors, between the different elements of the space infrastructure and between the space and ground segments. No longer will programmes or projects be considered in isolation or as self-standing events. In the words of the Resolution "... *underlines* that all the elements of this plan (long-term space plan) contribute to its coherence."

Completeness is called for in the disciplines of space activities and within the different programme sectors. Such an objective is a mark of the political awareness that there is an interlocking of different types of technology and science in space research and Europe must cover as wide a scope as possible. It is also a sign of the confidence governments have in ESA's ability to manage such programmes and European industry's capabilities to fulfil them.

Finally a balance must be achieved between the infrastructure and user programmes. The Resolution words this succinctly "- to pursue a European space programme as a coherent whole, with the spending on the tools needed for space activities and on the activities themselves appropriately balanced".

So the philosophy behind the future European Space Agency is established: every part must be seen and justified in the context of the whole. Nor is that the complete story, for ESA is seen as contributing to the establishment of an overall European policy in the field of technology.

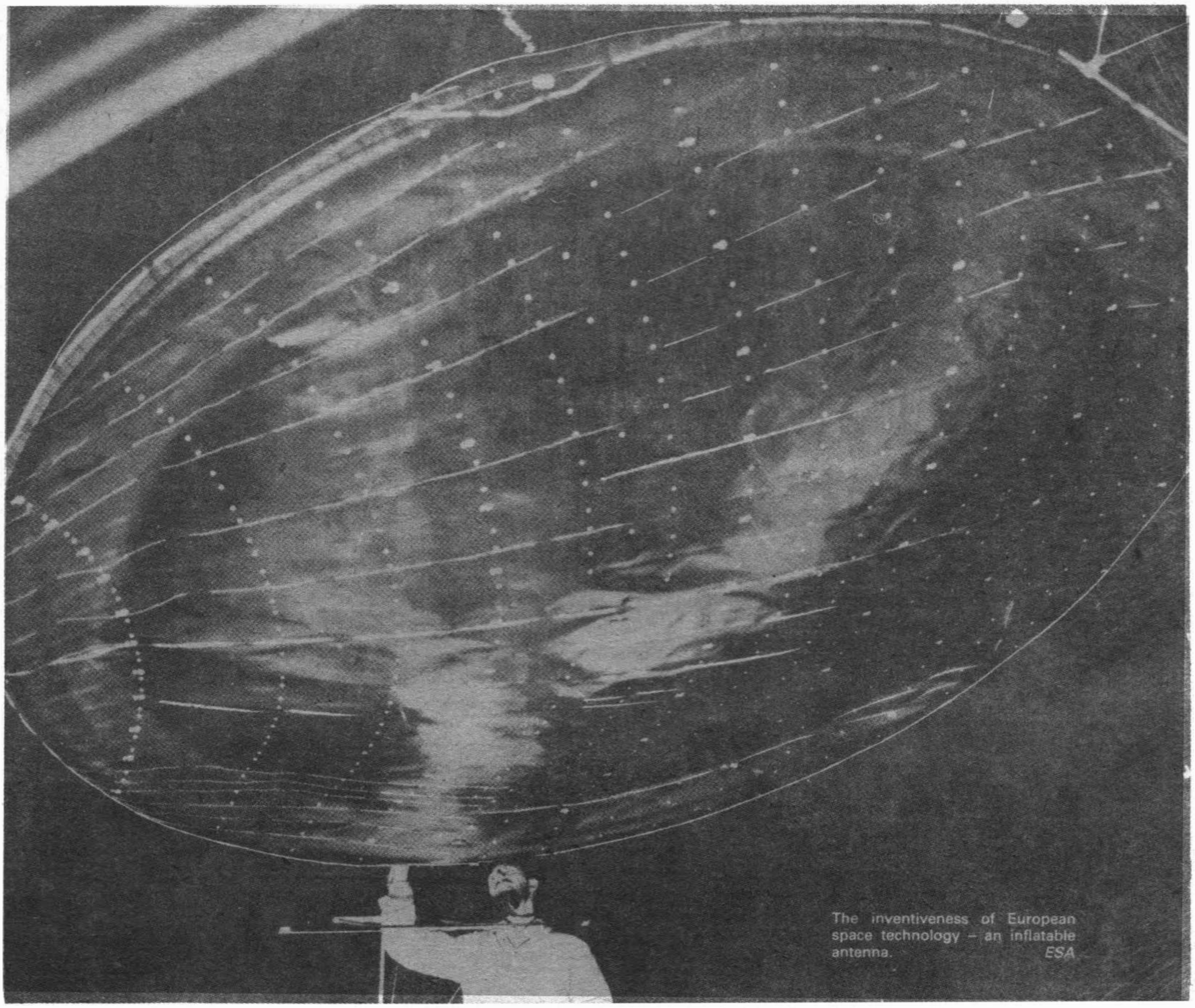
A Cautious Step Forward

While the Member States, with the exception of the UK, were prepared to continue the small growth in the space science programme deemed necessary to fulfil the "Horizon 2000" programme objectives and to approve the Earth observation, telecommunication, microgravity and Ariane 5 programmes, the decision was made for a phased approach in both the Columbus and Hermes programmes.

Why this difference? The established, traditional disciplines and programmes have built up a sufficient background of proof for the governments to be satisfied that they can judge the future in scientific and technical terms and in some cases commercial potential. Ariane 5 represents a special case in that the earlier and existing members of the Ariane family have shown the advantages to Europe of being in the forefront of the launcher market. A well documented assessment of the future market demands leaves no doubt that to retain its place in the late 90's and beyond there must be a new generation of launcher ready in time.

Columbus and Hermes represent the will of Europe to be an equal partner in manned space endeavours. Although Spacelab has been so successful, these programmes are breaking new ground and as such there are many aspects which need to be studied in considerable depth. For that reason the wise way forward was seen as a two-phase approach. In the first phase of three years the initial development will not only confirm the technical feasibility of the programmes but also give governments a chance to access the probability of the programme objectives being attained within the overall financial envelope.

EUROPEAN RENDEZVOUS



The inventiveness of European space technology – an inflatable antenna. ESA

The long-term plan, therefore, has two main streams in its development: those programmes which are seen in continuity through to the turn of the century, and those which will be developed in two phases, with a review after three years.

Industrial Approach

Understandably the Ministers spent considerable time over the industrial conseqences of their decisions. There is no doubt that the ultimate objectives include improving the worldwide competitiveness of European industry and to achieve that aim the technological level and industrial capacity in the space sector must be enhanced. Governments recognise that achieving technological eminence in Space also helps technological progress and innovation in other related and sometimes even diverse sectors. ESA therefore has the task of ensuring that countries have an industrial return of technological interest commensurate with their contribution to the budgets of the Agency. At the same time the principle of free competitive bidding has to be adhered to whenever possible.

The industrial policy is therefore not easy to administer, but the Agency knows that governments are showing a very healthy and positive interest in its activities when they insist on a defined industrial policy.

It is pertinent to stop for a moment to realise that ESA has a unique type of role in the progress towards unifying Europe. There is already a case for some economics student to track the way in which industry has aligned itself to meet the changing needs of the European space projects. The problems inherent in different practices, different management structures, different systems of measurement and above all fluid and multiple financial systems have been tackled and largely overcome. In the process many cultural and traditional barriers have been broken down and the gleanings of new ideas have sparked industrial concepts and working arrangements over a wide range of products. It is a ripple effect which no country can ignore in the long run, irrespective of short-term considerations.

A new element enters the scene at this stage, namely the role of private enterprise financing in Space. It is worth quoting the Resolution more fully on this point.

The Director General is invited:

- to identify potential private sector funding sources for programmes whenever possible,
- where early private sector funding is not possible, to consider means of industrial and user involvement in design and timing decisions,
- where no private sector money is involved, to identify whether users are prepared to take over operational or recurring cost following development,
- to set milestones project by project,

Contest for New ESA Facilities

The ESA ground infrastructure has become a critical subject of negotiations between the main member states following the Hague meeting, *writes Theo Pirard.*

Currently, ESA operates facilities in the Netherlands (ESTEC, Noordwijk), Germany (ESOC, Darmstadt) Italy (ESRIN , Frascati and Fucino station), Belgium (ESTRACK, Redu), Spain (stations at Villafranca and Canary Islands), France (Headquaters at Paris, Guiana Space Center at Kourou, Toulouse offices).

New activities of the ESA Long-Term Programme will mean establishing new facilities for the control of spacecraft, payload preparation (e.g. Columbus), astronaut training and refurbishment of Hermes.

Each major member state would like to acquire some of the new ESA establishments:

- France is bidding, as major partner of Ariane 5 and Hermes, for the main ground facilities which include: Ariane 5 preparation and control centres, Hermes integration and refurbishment facilities, manned space flight control centre at Toulouse, Hermes landing strip, astronaut training centre and payload preparation establishment.
- Germany is proposing two DFVLR establishments for Columbus and Hermes facilities: the German Space Operations Centre (GSOC) of Oberpfaffenhofen, Munich, (qualified the Spacelab D1 mission for manned flights) to control Columbus APM (Attached Pressurised Module) and MTFF (Man-Tended Free-Flyer) missions; the Porz-Wahn Centre (near Cologne airport), already used for Spacelab training facilities and as Microgravity User Support Centre (MUSC), to train the crews for Columbus and to prepare payloads for Columbus and Hermes.
- Italy is seeking to acquire at Torino (Aeritalia Space Systems) the control centre and preparation facility of the Columbus APM missions; it also is requesting for Fucino the control centre for the DRS spacecraft (Data Relay Satellite).
- Belgium is looking for improvements at the Redu ESA Station to control the next European technological communications satellites; for the location near Brussels airport of the astronaut training centre (Hermes missions) or for the establishment of a microgravity payload preparation facility in the Flemish part of the country.

where the case for increasing the existing private sector involvement would be specifically addressed.

One specific case is mentioned, when it is acknowledged that the Director General is actively pursuing the possibility of the private sector taking part in the funding of the data relay satellite.

The idea of private sector money being used highlights several aspects of space research which must be taken into account before there can be substantial movement in that direction. Private sector money has to answer to stockholders who expect a return on investment within a reasonable time. To this extent fundamental research is unlikely to attract private sector money because it holds out little hope of commerical potential in itself. Even the early stages of operational systems are difficult to sell to commercially minded finance holders because of the inevitable time span before the systems become operational. Thus the long-term future for commercial involvement in financing space projects is likely to come in those programmes where the production possibilities or the user potential is held to be on a commercial scale.

Space Station Negotiations

The Ministers approved a separate resolution on the Columbus programme, due account being taken of the fact that negotiations were not yet completed with the US Government. They confirmed Europe's interest in participating with the USA in an international space station and accepted NASA's overall programme coordination and direction regarding the manned base. At the same time they required as minimal essentials for Europe's participation that the responsibility of ESA should be recognised in the design, development, operation and utilisation of the elements that Europe will provide. It is also a condition that ESA remains in full control of the design, development, operation and utilisation of the man-tended free flyer and the European polar platform, within the overall space station safety requirements.

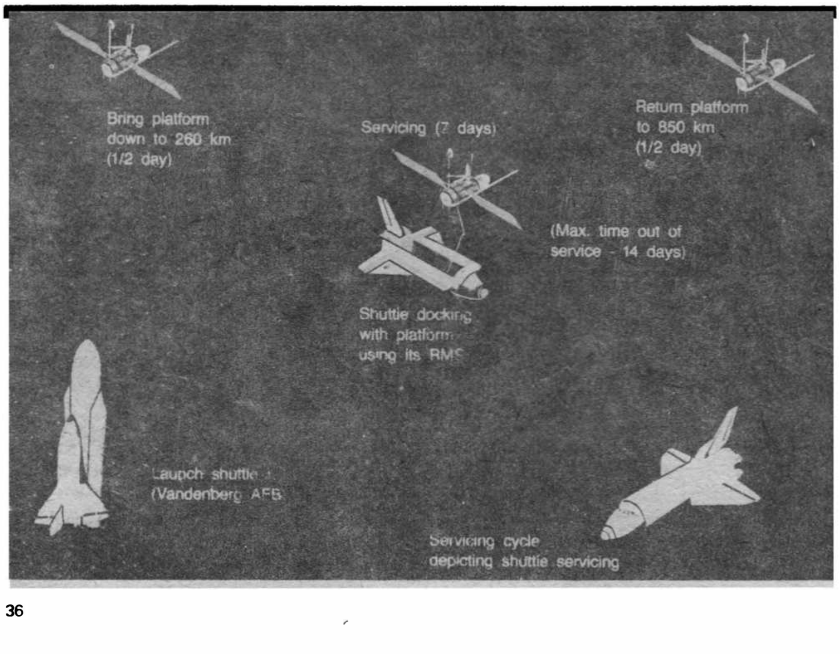
Meanwhile, as indicated above, work is to progress on Phase 1 of the two-phase approach towards the development of three elements:

- the attached pressurised module (APM) which would be an integral part of the international space station,
- the man-tended free flyer (MTFF) which would orbit within a short distance of the station and be serviced by Hermes every six months,
- the polar platform (PPF) which would be dedicated primarily to Earth observation.

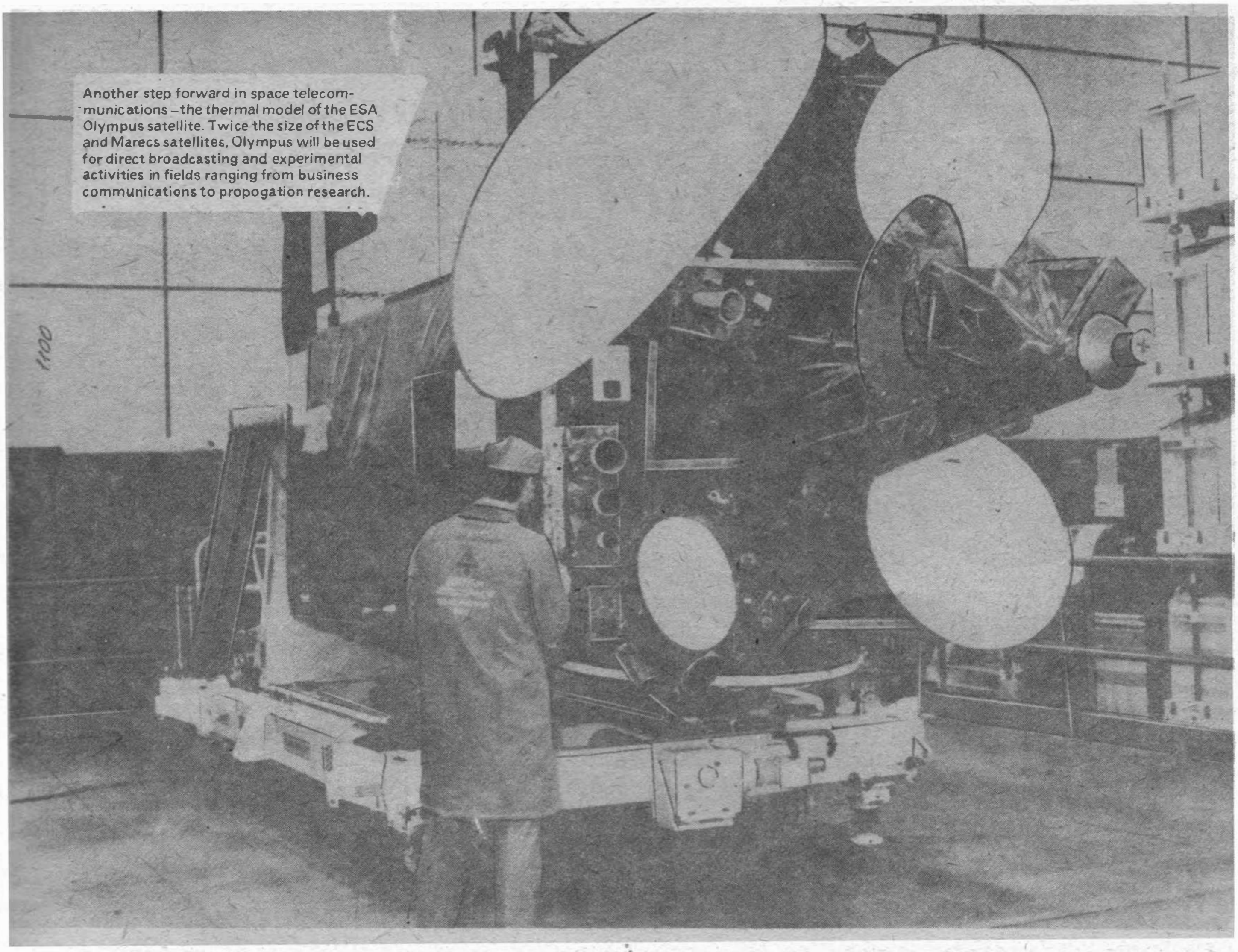
Europe On Course

The Ministers have given Europe more than a blueprint: they have announced to the world that Europe, from which so much of the industrial revolution had stemmed, was taking its rightful place amongst the leaders of the new hi-tech revolution in which space exploration and exploitation is so important.

An artist's impression of one method of servicing a polar platform *ESA*



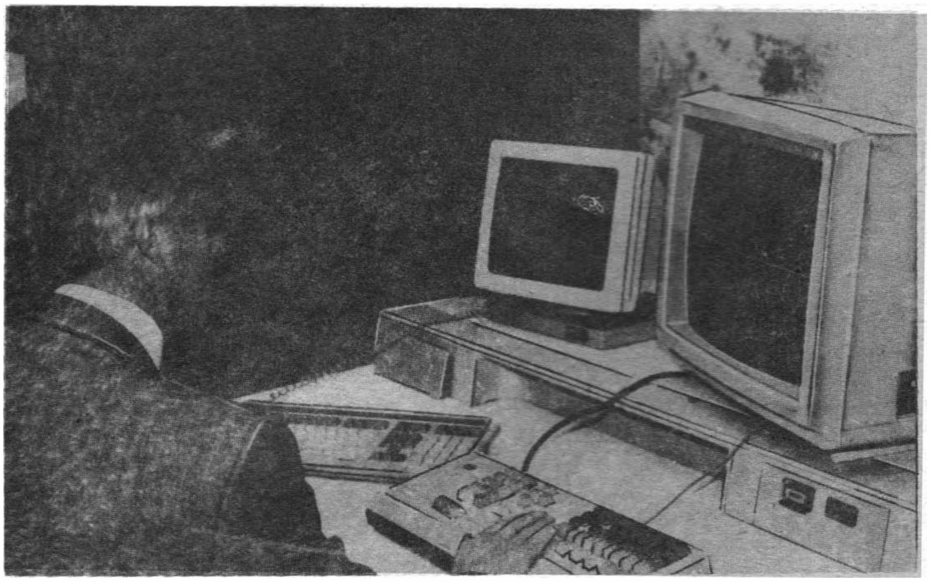
Part II of this report by Norman Longdon, who is Head of ESA's Publications Division, will contain details of the various programmes in the ESA long-term plan



Another step forward in space telecommunications – the thermal model of the ESA Olympus satellite. Twice the size of the ECS and Marecs satellites, Olympus will be used for direct broadcasting and experimental activities in fields ranging from business communications to propogation research.

Ensuring that satellites reach their nominal orbit and are maintained there calls for great skill and knowledge. The control room at ESOC (Darmstadt, FRG) is seen here during rehearsals for the ECS-4 launch.
Picture Report – Amsterdam

UK Firms Expect to Lose Hermes Work



John Butcher, Under-Secretary of State for Information Technology, takes a first-hand look at computer development methods employed by BAJ (Rocket Motor and Stored Energy System divisions) of the UK during the SPACE '87 exhibition — P J Fulford

The UK Government's decision not to participate in the ESA Hermes programme is likely to cost UK companies dearly, according to Mr. J.H. Brewer, Head of Marketing at Singer Link-Miles Space Systems.

Mr. Brewer says the extent of lost business will probably run into hundreds of millions of pounds during the next 15 years.

Following the Hague meeting it was divulged that a European consortium led by Singer Link-Miles had been judged to have offered the best technical solutions to produce "Studies and Specifications of the Flight Simulator for Hermes crew training"

This small value study, scheduled to commence early this year, made proposals for basic training of astronauts and more specialised mission training.

Singer Link-Miles, and potentially other UK companies, now look certain to lose the opportunity to participate in the design and production of these training facilities.

Seven UK companies will suffer similarly in other parts of the Hermes programme and the result will not only be the loss of prestigious contracts but in the failure to build up facilities and products which could be marketed elsewhere.

Hotol's International Future

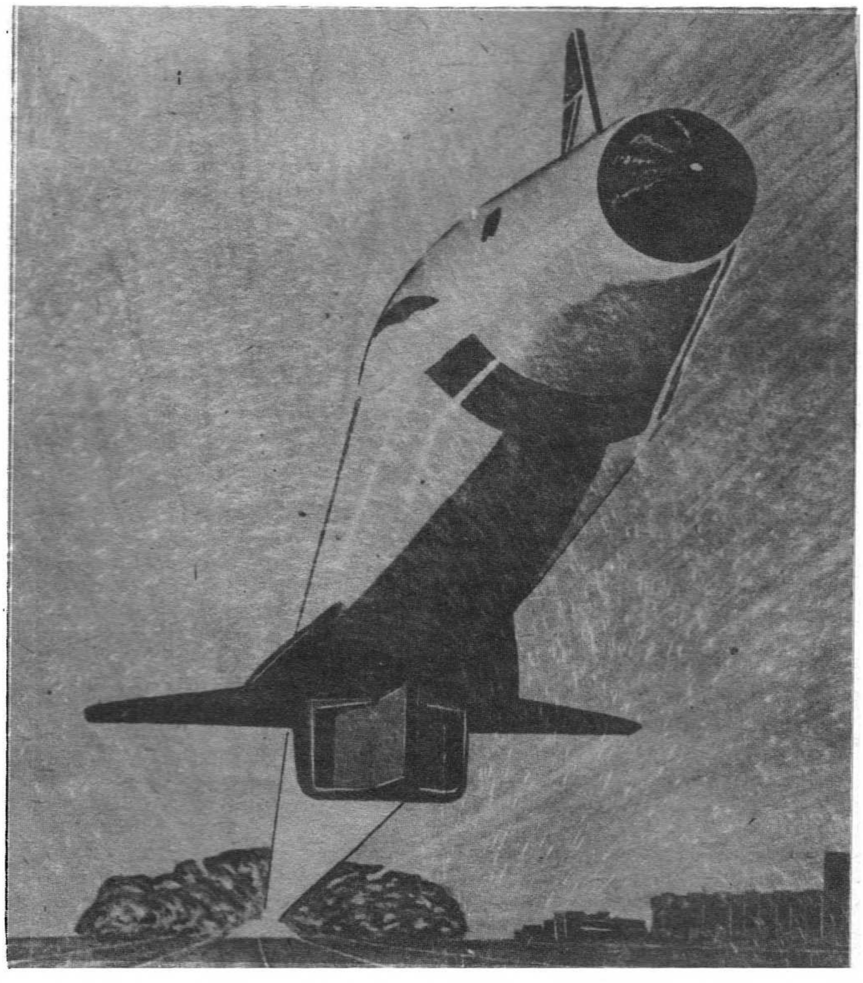
The UK government believes that it is now increasingly unlikely that the British Aerospace/Rolls Royce Hotol proposal will be developed in the 1990's as a European Space Agency (ESA) project.

In response to questioning on Hotol in the House of Commons following his attendance at the ESA ministers' meeting in the Hague, Mr Kenneth Clarke told MP's there was no interest within ESA in taking it on.

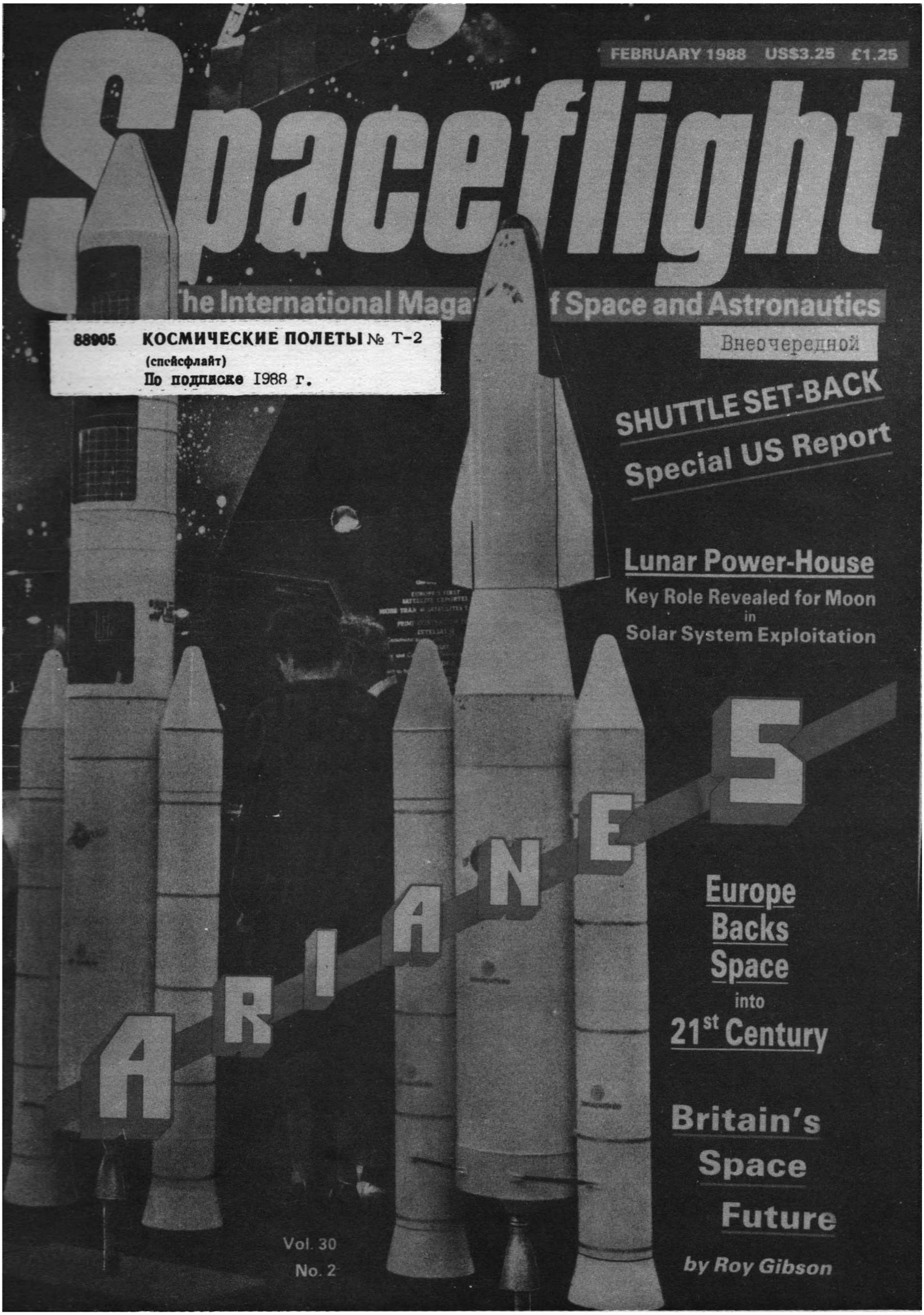
At the moment it is perceived as a competitor and they do not want Hotol to go forward, he stated.

"We have to consider with our own industry how to proceed, and it is not through the route of ESA at The Hague. I have encouraged British Aerospace to have discussions with the Germans and the Japanese, whose industries are interested. We will have further discussions but there is no point in going it alone on a project like Hotol.

"If the European Space Agency is not a collaborator, there is no point in my throwing money down the drain into ESA on the Hermes project, which is a competitor. I have to continue the exploration for other international collaborators who might be interested in taking Hotol further."



Will 1988 see the Hotol project take off in a new direction? — Painting. I. Moule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Backs
Space
into
21st Century
Britain's
Space
Future
by Roy Gibson
Vol. 30
No. 2

ВНИМАНИЮ ПОДПИСЧИКОВ!

В связи с задержкой поступления из-за границы журнала "Космические полеты" № I высылаем вам последующие номера.

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 30 No. 2 February 1988

Front Cover: Ariane 5 is scheduled to take over from Ariane 4 as Europe's space launcher in the mid-1990's. Its higher performance rating will maintain its commercial viability against mounting international competition for launching the heavier geostationary spacecraft of the 1990's. The left-hand model is cut away to show its multiple launch capability of 2 or 3 satellites to geostationary orbit. Ariane 5 will also be up-rated in reliability making it not only more attractive for launching expensive unmanned payloads, but also enabling it to serve as the carrier of the Hermes spaceplane as shown on the right. A special report on Ariane 5 development appears on p.78.
P.J. Fulford

Picture: Looking back at the Earth and Moon, by *J. Baum.*

The Sally Ride Report to NASA (*Spaceflight*, November 1987, p.356) called for an 'Outpost on the Moon', which would build on the legacy of Apollo and lead to a new phase of lunar exploration and development.

The outpost would, according to the report, support scientific research and exploration of the Moon's resource potential and would represent a significant step toward learning to live and work in the hostile environment of other worlds.

An abundance of solar electrical power is the Moon's leading resource which opens up the prospects of materials processing and manufacture on a massive scale. In this article *A.T. Lawton* and *D.P. O'Grady* set out their ideas for progressively developing the Moon to become the Solar System's power-house and main industrial facility by the 22nd Century. It is not, however, a plan to be shelved for the future. A start date of 1995 is envisaged.

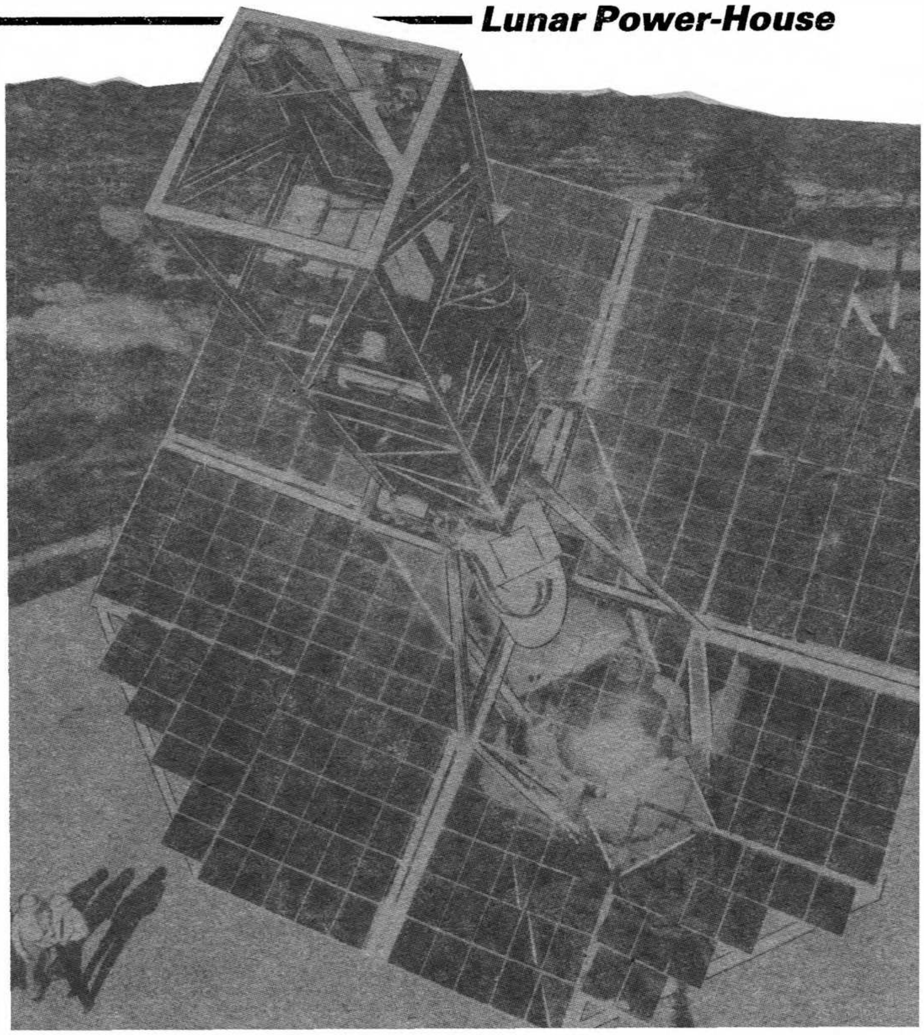
LUNAR POWER-HOUSE...

.... Workshop of the Solar System

Following the discovery of 'high temperature' superconductors, their use on the Moon has been suggested for power grids, electromagnetic launchers and several allied items – all cooled by natural lunar refrigeration [1].

We now outline how, by means of an electrical grid system, all key areas of the Moon could have solar-generated electrical power on a continuous basis for the manufacture of metals, alloys, insulating fibres and new forms of superconducting crystalline structures.

The mineral wealth of the Moon remains vague, but its exploitation by solar energy and electrical power (non-polluting and clean) would allow the production of the large quantities of material required for the exploration and exploitation of the whole Solar System. Also, the principal by-product of the process could be oxygen, which can be used to provide an atmosphere and as a propellant for rocket propulsion.



A prototype solar concentrator under test by the Harris Corporation and Rockwell International as a means of collecting the Sun's energy without the need for massive arrays of photovoltaic cells. Although being developed for use on the international space station, such technology could prove of immense value in providing power for an early Moon base and exploitation of lunar resources.

A Ring Around the Moon

The first phase of a possible long-term programme for a complete electrical power "ring" of superconducting material would be the laying of a comparatively short length in a flat, lowland area. Other cables would later be laid in similar lowland areas and these would be progressively linked up to form a larger and longer network until eventually the Moon would be completely girdled.

Perhaps it would be more suitable to lay out the power grid as a polygon with its enclosed area facing Earth. Not only would it be easier to lay since most of the lunar lowlands face Earthwards, but continuous communication could be maintained with Earth.

However, such a layout would lose the advantage of continuous working at a constant power level. A "ring around the Moon" on the other hand would allow continuous power to be drawn by anyone connected to the grid. Storage batteries, extremely expensive for the power levels considered, would be unnecessary. In practice, the "Polygon" could be expected to precede the "Ring".

The remarkable properties of the new superconducting crystalline materials have been outlined in ***Spaceflight*** (November 1987, p.358) and a more comprehensive survey is given in Ref. 2.

Building the Ring

The moon has a mean diameter of 3470 km (2160 miles) corresponding to a mean circumference of 10,920 km (6786 miles). This represents the absolute minimum length of a Moon Ring and, allowing for the loops and diversions that local territory would demand, the final length of a complete superconductor girdle would lie between 15,000 and 20,000 km – the latter figure being an absolute maximum.

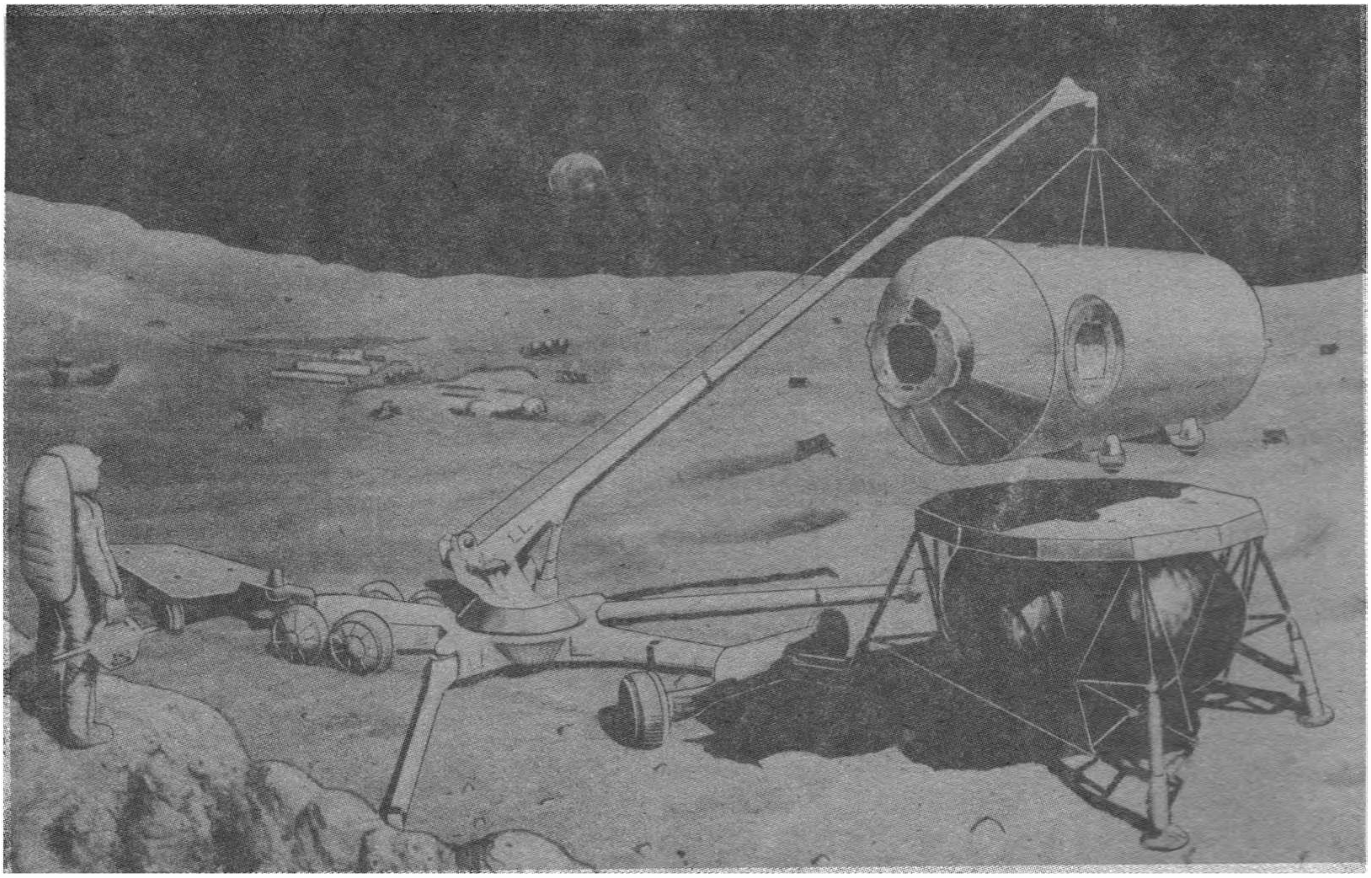
The superconducting ring would cut the cost of energy produced to such an extent that rapid industrial development would follow.

The laying of such a cable is on a parallel scale to that of laying a railway such as the new Soviet trans-Siberian railroad which is about 8500 km long. Over the last 165 years thousands of kilometres of rail track have been laid throughout the world and if we allow a similar timescale to elapse, starting from 1995, then by the middle of the 22nd Century (around 2160) the Moon Ring Grid should be complete with all peripherals installed and connected. The final result would be a complete launch base for Solar System exploration, a major industrial complex for supplying processed material and finished products, and finally a stepping off point for the exploration of nearby interstellar space.

This plan would be closely integrated with properly phased milestones and without over-extending resources and effort in any particular phase. The approach would be much better than that adopted for the Apollo Program which achieved its goal but failed to build on it by establishing suitable follow-on goals. It is in keeping with the gist of the Ride report [3].

An Outline Programme

Starting in 1995, the initial stages would consist of installing a solar panel power generator with the panels connected to each other and to its lunar-base consumers. The station could be installed at a suitable site in (say) Mare Serenitatis, Mare Imbrium



Artist's illustration of how a mining operation may look on a Lunar base in the first part of the next century. *NASA*

or Mare Tranquillitatis – the actual choice of site is about equal. All three areas could subsequently be established as prime sites and linked together.

Eventually Mare Crisium and Mare Marginalis could be linked as could Oceanus Procellarum. Such a combination would assure continuous power at a sustained level for over 14 days.

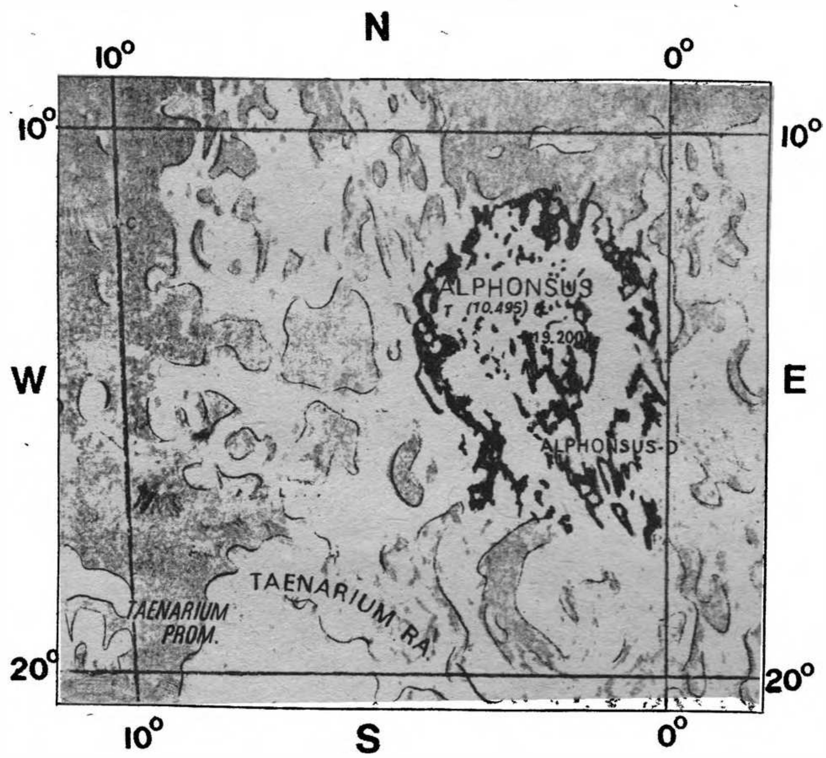
Ultimately low level features on the farside of the Moon, e.g. Mare Mosciense and others, would be built on and linked to form a continuous power level grid with extremely low electrical losses. The question arises, how much power could we obtain?

Moon Grid Power Level

The total area of the Moon may be taken as 6.087 x 10^{18} square metres. The solar constant is slightly higher on the Moon than on Earth, due to the latter's atmospheric absorption, and a round figure of 1,500 Joules per square metre per second would not be far out for a zenith Sun.

Since the Sun only illuminates half of the Moon at any time we can assume an actively illuminated area of approximately 3 x 10^{18} sq m and a vertically incident energy of 3 x 10^{18} x 1500 J per sec or in electrical terms 4.5 x 10^{21} Watts. This is an enormous amount, representing the output of one million million (10^{12}) of the most powerful generating stations in present use (of about 4500 MW each).

Of course we cannot use all of this energy, but if we take solar cells of only 10 per cent efficiency and assume that we would use only 0.001 per cent of the Moon's surface, this still represents an electrical power level of 4.5 billion Megawatts!



Alphonsus – a crater observed emitting hot carbon vapour on November 3, 1958 by N. Kozyrev.

There is another reduction inasmuch as we have been calculating power levels for a zenith Sun. However the Sun rises, moves to zenith and then sets during the 14.5 days of lunar sunlight, the power level at any generating station being proportional to the sine of the angle of the Sun's direction with the horizon. If we take half power levels, corresponding to 30 degrees after sunrise and 30 degrees before sunset, a power level of 2.25 billion Megawatts is obtained for our chain of solar power stations.

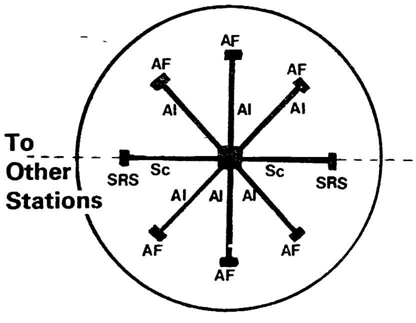
The estimate immediately tells us that the actual area of the Moon needed for industrialisation on a realistic scale would be very much smaller than the adopted value of 0.001 per cent and that the various sites would be further apart than may have originally been conceived.

The use of superconductor techniques is therefore essential for future settlements and complexes. Solar power is cheap, constant and plentiful on the Moon, but to interlink solar stations with ordinary conductors would give rise to prohibitive losses, the only suitable bulk metal available being aluminium which is the second best metallic conductor to copper. Superconductor materials of the rare-Earth "high temperature" type occur naturally in lunar materials and it may therefore be possible to undertake their manufacture on the Moon.

Carbon on the Moon?

Cheap electrical power on the scale considered here would revolutionise the production of clean, vacuum-melted pure metals and special alloys, and would allow manufacture of silicon for further solar panels.

It would also revolutionise the manufacture of certain chemicals but these items could require carbon and water – neither of which is known to exist on the Moon. Carbon was however reported by Kozyrev observing on November 3, 1958 from the 1.25 m telescope at the Crimean Astrophysical Centre.



'Tranquility' solar power complex. Key: AF (Auxilary Feed), Al (Aluminium), Sc (Superconductor) and SRS (Superconductor Ring System).
A.T. Lawton

By means of an electrical grid system, all key areas of the Moon could have continuous, solar-generated electrical power.

He observed a reddish glowing patch for about 30 minutes near the central peak of Alphonsus. Kozyrev, obtained a spectrum and deduced the presence of carbon and a glow temperature of 1300 K.

No satisfactory explanation has been forthcoming either for this or other glow observations reported from time to time. Although unlikely, there may be traces of methane still lurking deep in the lunar crust. Both hydrogen and carbon would then be available – and Gold's theories of methane [4] buried in primeval rocks finally proven!

A Lunar Workshop?

The Moon is destined to become the workshop of the Solar System. Every tonne of material used in low-Earth orbit requires at least 20 tonnes of fuel and carrier rocket to place it there and landing on the Moon requires roughly 30 tonnes of fuel and carrier rocket. If materials for a Moon Base can be made on the Moon then clearly enormous savings are possible. With the consumption of metals doubling roughly every 35 years, we believe that the super-conducting "Ring Around the Moon" is *the* vital link that would cut the cost of energy produced to such an extent that rapid industrial development would follow. As this article is written further work on superconducting cables has been announced by ICI [5].

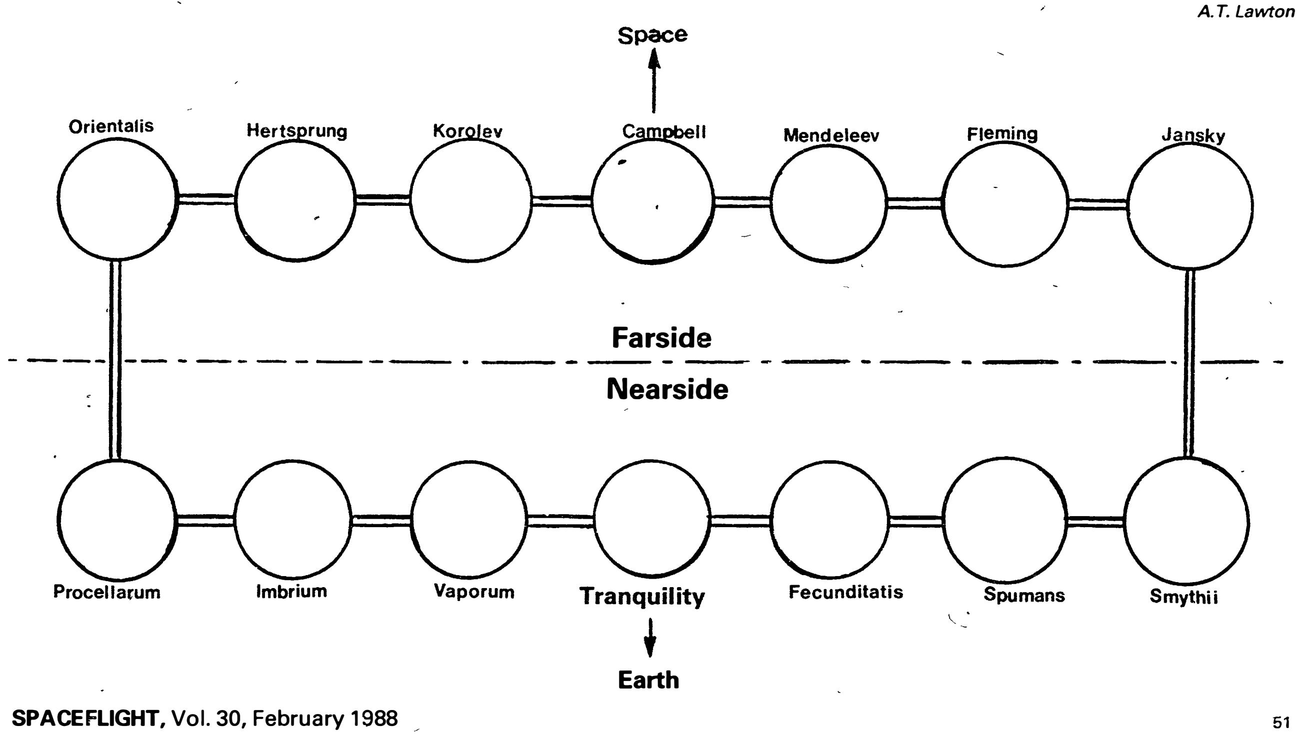
A Ring Around Mars?

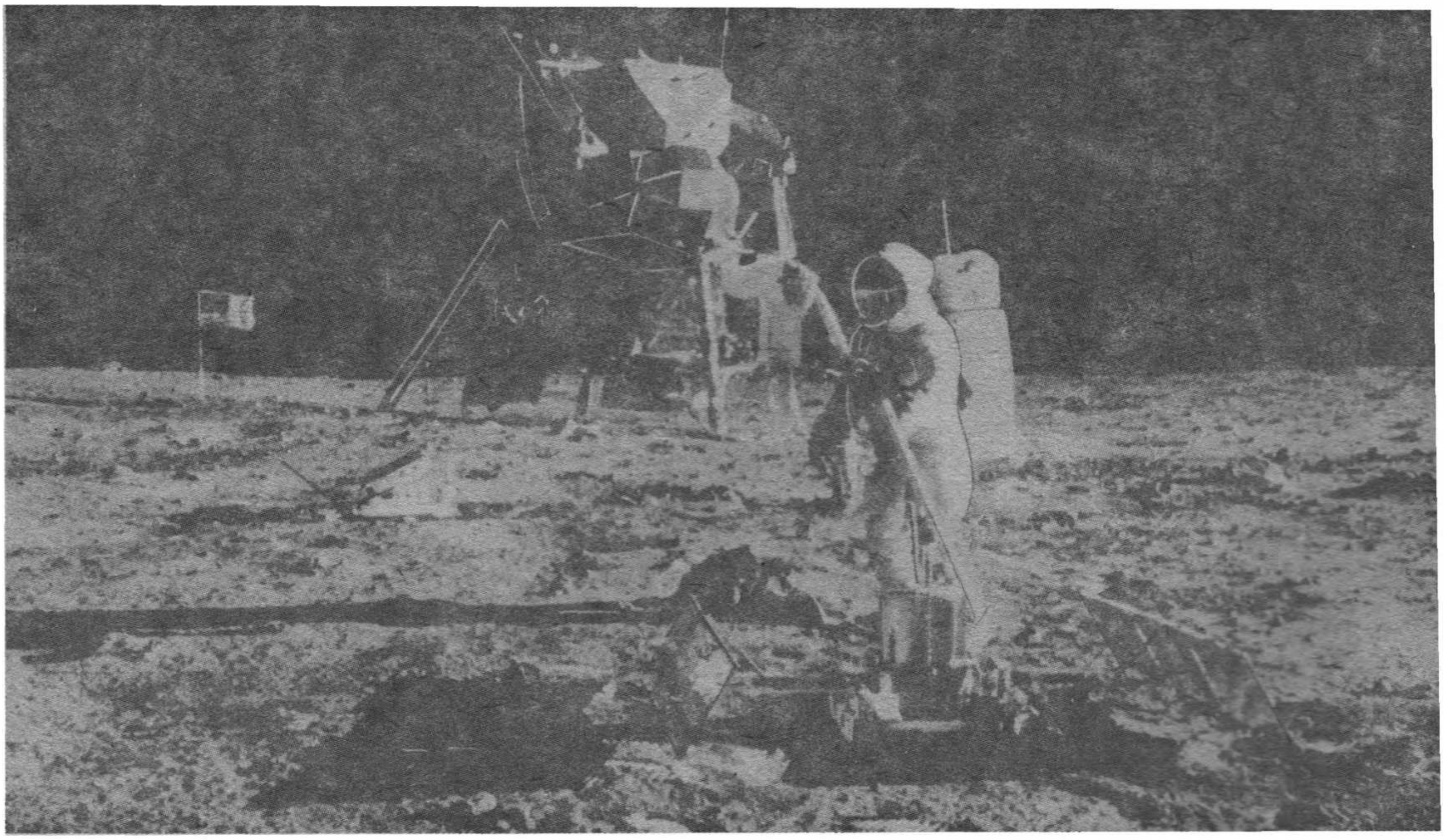
The plans outlined above might seem to lend themselves to energy sources on Mars. This is not so. Although Mars has an average climate that could probably support naturally refrigerated superconductors, two major factors mitigate against such exploitation. They are:

i. The very much lower solar constant (only 600 J per square metre per sec some 2.5 times less than for the Moon). This is above the atmosphere, and would be correspondingly less at the surface.

ii The atmosphere itself is very dry

Outline of Superconducting Ring principal stations, each approximately 1000 km apart Anything connected to this complex could receive continuous power.
A.T. Lawton





The first lunar landing of the Apollo Programme brought solar electrical power to the Moon. Apollo 11's scientific experiments are shown being deployed on the lunar surface near the lunar module. In the foreground is the seismic experiment package whose electrical power subsystem generated 34 to 46 watts using two solar panels, angled for optimum reception of sunlight during the long lunar day. Using the same basic principles, vastly greater sources of power generation are proposed as a key feature of lunar development during the next century. This photograph was taken by Neil Armstrong with a 70 mm lunar surface camera on July 20, 1969 as Edwin Aldrin deploys the packages. *NASA*

and dust laden. Solar panels would therefore not only have to be larger but would be coated with fine dust layers further reducing the efficiency of power generation – and requiring constant attention.

The 24 hour rotation period of Mars suggests that, if solar power is adopted, a series of local power stations maintained at night by storage batteries may prove (at least initially) a more economical solution.

Conclusion

The almost unique characteristics of the Moon (long day period, high solar constant, no atmosphere and no weather problems) make it an ideal site for a superconducting network of power distribution with native produced silicon solar panels as the power source.

We strongly feel that these points should be emphasised in any addenda attached to the excellent outlines already contained in the Ride Report to NASA.

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1 A.T Lawton, P.P. Wright 'Superconductors Lift Lunar Base Prospects', *Spaceflight* November 1987, pp 358-361
2 Khurana A. 'Superconductivity seen above boiling point of Nitrogen', *Physics Today*, April 1987, pp 17-23.
3 Ride, S et al 'Leadership and America's Future in Space' Report to NASA 1987 – summarised in *Spaceflight* November 1987, pp 356-358
4. Lawton A.T 'A Window in the Sky', pp 63-67, published by David and Charles, 1979
5 Matthews R. 'Researchers Hail Success in Electrical Conductors', *The Times*, November 3, 1987, p 3.

Lunar Base by 2005

The next NASA initiative beyond the space station could be the establishment of a significant lunar base by the year 2005.

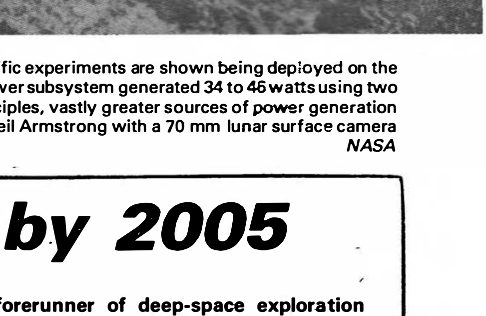
Five studies, each of one year duration, on how a base could be built and operated on the Moon together with an assessment of its uses and benefits are to be conducted under contracts or grants administered by the NASA Johnson Space Center. Two of the studies, which will be in-house, using civil service and contractor manpower at JSC, will deal with utilisation of a lunar base and advanced lunar transportation.

The Moon represents the closest source of materials outside of the Earth and from here transportation into space requires about five per cent of the energy required for putting similar amounts from Earth into space. As the Moon is relatively rich in certain elements, such as oxygen, silicon, iron, calcium, aluminium and magnesium, a permanent lunar facility could use these resources to support a growing space infrastructure and the settlement of the Solar System.

The lunar initiative is seen as a test bed for those technologies which will enable humans to live away from the Earth for extended periods with reduced dependence on the Earth, and so be a forerunner of deep-space exploration to, for example, Mars and its moons.

Groundwork for these future plans is expected to be laid at the forthcoming second Lunar Base Symposium to be held in Houston, Texas in April. More than 230 abstracts have been submitted to the conference's programme committee. Proceedings of the first symposium held in October 1984 have appeared in the book entitled 'Lunar Bases & Space Activities of the 21st Century', published by the Lunar and Planetary Laboratory, University of Arizona, Tucson, AZ 85721, USA priced $20.00.

Lunar mining operation on future Moon Base. *NASA*



INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Japan Plans Lunar and Planetary Missions

Projects for the exploration of the Moon and planets during the mid 1990s are being planned by the Japanese Institute of Space and Astronautical Science (ISAS).

The Moon is seen as a key target and scientists in Japan believe they can bring about a revolution in lunar science if the structure and composition of as yet unexplored areas can be revealed.

The ISAS working group has been developing a variety of remote sensing instruments, including a gamma-ray spectrometer, and at the same time are striving to develop a penetrator.

According to one mission plan, several penetrators would be dropped from a lunar orbiter to penetrate the Moon's surface. The lunar orbiters would be unmanned stations, carrying out continuous scientific observations.

Each penetrator will contain a seismometer and a heat-flow meter. The setting up of several such devices will allow investigation of the Moon's inner structure by sensing the differences in phases that seismic waves propogate in the lunar interior.

Such techniques will also be applicable to the examination of the inner structures of comets, asteroids and other planets with solid surfaces, such as Mars, Venus and Mercury.

ISAS is also looking at the possibility of a comet-sampling mission as a follow-on to its highly successful probes in 1985/6 to study Comet Halley.

Return of cometary material from a comet would be the first extra-terrestrial material brough to Earth since the Moon-rock samples of the Apollo era.

However, comet samples, unlike those from the Moon, will not have been modified by geological processes and can be picked up directly from the comet without landing.

Once returned to Earth, the comet samples can be treated by the most advanced techniques of laboratory analysis to determine their composition and structure. Such analysis will contribute to the investigation of the condensation processes in the solar nebula.

According to the mission studies carried out so far by the ISAS team, the baseline mission chosen for the time being is a free-return to Comet Churyumov-Garasimenko.

Exploration of Venus is another area of immense interest to Japanese scientists. One possible ISAS mission to this planet will involve an 'aerocapture' procedure (to save on propulsion weight) for orbital insertion.

Satellite Still Transmitting After 20 Years

Pioneer 8, launched from Cape Canaveral on December 13, 1967, is now in its 21st year of operation after some 11 billion miles of interplanetary travel.

Design specifications called for the 140 lb spacecraft to last six months, but NASA's Ames Research Center continues to receive signals from Pioneer 8 two decades later.

Pioneer 8 was the third satellite in a four-spacecraft series built for NASA by TRW. All were designed to study solar flares and related phenomena.

The series provided valuable information on the turbulence of the solar wind and how the wind affects the Earth's magnetic field. The first satellite in the series, Pioneer 6, is the oldest functioning spacecraft in interplanetary space, having celebrated 22 years of operation on December 16, 1987. The only satellite in the series that is not operating is Pioneer 9, which was launched in 1968. NASA officially declared Pioneer 9 dead early last year.

When launched, Pioneer 8 was equipped with eight instruments. All but the electric field detector have stopped providing information, either because of the failure of the spacecraft's solar sensor or its degraded solar power. NASA scientists suspect that the large number of solar flares that Pioneer 8 has been exposed to and its long, relatively close exposure to the Sun's ultraviolet radiation have damaged these power systems.

Pioneer 8 has transmitted an estimated 11 billion bytes of information during its 20 year lifetime. It orbits the Sun once every 388 days at a distance from Earth that ranges from two million to 186 million miles.

Deep Space Antennas

Two lines of text were inadvertently omitted from the fourth paragraph of Dr. W.I. McLaughlin's report on Deep Space Antennas (January 1988, p.20). The final three lines should have read: the Parks 64m radio telescope in Australia will be arrayed with the 70m DSN antenna; and the 64m antenna at Usuda, Japan will be brought into the Voyager 2 tracking network.

Canadian Experiment for Soviet Mission

When the first Soviet Interbol spacecraft combination is launched on July 13, 1990, with a Proton rocket a Canadian experiment will be included on a Soviet space mission for the first time.

The 20 kg Canadian experiment package is an ultraviolet imaging sensor very similar to the UV instrument that flew aboard the Swedish Viking satellite in early 1986. Ultraviolet images will be produced of the aurora to aid in the 11 nation Interbol project which will study the Earth's magnetosphere and the mechanisms that drive the aurora.

As on Viking, the ultraviolet imager for Interbol is a project of the University of Calgary in conjunction with the National Research Council of Canada. Dr. Leroy Cogger is the principal experimenter, and Canadian Astronautics Ltd the hardware contractor.

Two pairs of spacecraft will be launched by the Soviets, each pair comprising a main bus based on the Prognoz scientific satellite and a small sub-satellite similar to the Czechslovakian Magion satellite. One pair will be placed in orbit with a 200 000 km apogee, and the other pair (which will carry the Canadian instrument on the main vehicle) will orbit at a maximum altitude of 20 000 km.

First Launch in Early 1990 for Brazil

Brazil, working with European industry in developing its own space technology and launch facilities, is planning the first launch of its own rocket in two years' time, *writes Theo Pirard.*

The Brazilian Instituto de Atividades Espaciais (IAE) and Instituto de Pesquisas Espaciais (INPE) are cooperating with German DFVLR, French Aerospatiale, Belgian ETCA and French Intespace.

IAE is responsible for the development of solid Sonda rockets (currently launched from Barreira do Inferno, near Natal) and the VLS (Vehiculo Lançador de Satellite) project. VLS will be a four-stage launch vehicle capable of putting some 200 kg into a 600 km circular orbit; the first launch is now scheduled for early 1990.

A new launch site – Centro de Lançamento de Foguetes de Alcantara – is being established with modern airport and accommodation facilities in the north of Brazil relatively close to French Guiana.

INPE is working on two types of small spacecraft, to be launched with the VLS vehicle from the Alcantara site within the MECB (Missao Espacial Completa Brasileira) project.

The first type is the SCD (Satellite de Coleta de Dados) spacecraft: weighing 115 kg (with 23 kg payload), SCD-1 and SCD-2 will be placed in 750 km circular orbits with 25 degree inclination and they will be used to collect data from remote platforms (PCD or Plataforma Coletoras de Dados) in Brazil.

The second type of satellite is the SSR (Satellite de Sensoriamento Remoto) spacecraft: weighing some 150 kg, SSR-1 and SSR-2 will be launched – starting in 1993 – into 600 km Sun-synchronous orbits and will take pictures in three spectral bands with 40 m resolution. To prepare for this MECB project, INPE is building near its headquarters at Sao Jose dos Campos the LIT (Laboratorio de Integraçao e Testes) facility at a cost of 30 million dollars.

Space 'Weather' Forecast

Japanese scientists are looking ahead to the first part of the next century when regular space 'weather' forecasts will be needed to warn people living in orbit of imminent radiation danger.

Radio waves, x-rays and gamma rays, infrared and ultraviolet rays and radioactivity from the Van Allen belts could all be potential sources of hazard. And in addition to affecting people they can also damage space equipment.

The Japanese Radio Research Laboratory of the Ministry of Posts and Telecommunications plans to undertake space-weather forecasting by measuring dangerous and non-stationary changes in the space environment to ensure the protection of human health and the safe operation of space equipment.

This research and development project is specifically intended to provide:

(i) Additional ground facilities for observing the Sun-dominated space environment.
(ii) A data processing system for domestic and foreign observation data and space weather forecast models.
(iii) An in-situ space environment observation capability through measuring equipment mounted on routinely operated artificial satellites.

As weather forecasts on Earth have an influence on human life on the Earth, spaceweather forecasts are expected to have a significant bearing on the safety of activity in space.

Workers on a future manned space factory may start the day by listening to a forecast something like this: "There is a 70 per cent probability that a large solar flare of over strength three will occur on December 12, between 0 and 6 hours Universal Time (UT). If you are going to be working in space or going out of the lunar station, please confirm the positions of the radiation shelters. There may be interference to satellite-to-satellite communications in the frequency range of up to ... GHz. Spacecraft flying in the H region within the magnetosphere are likely to become electrically charged due to the influence of the previous flare on December 10. Solar activity will continue for the next few days but will diminish by next weekend, and the magnetosphere will become calm again. That was the spaceweather forecast for 0 to 6 hours UT on December 12."

Science & Technology in Japan

India Develops Cryogenic Engine

While Brazil is developing its own launch capability with a small launcher (see above), India's ambition is to acquire for the mid-1990's its own domestic powerful vehicle to launch spacecraft in GTO. The Indian Space Research Organisation (ISRO) is preparing an Ariane 3/Atlas-Centaur-type launcher for the Insat II generation multipurpose spacecraft.

The Indian Department of Space has decided to use an indigenous cryogenic stage and engine for the GSLV (Geo-Synchronous Satellite Launch Vehicle).

ISRO plans its first test launch of the GSLV in 1993-94. It is aimed at placing 2.5 tons in GTO, making India completely autonomous for space operations, with practical applications which will be useful for developing countries. ISRO will also offer launch services with the Indian PSLV (Polar) and GSLV (Geo-Synchronous) rockets.

Using the PSLV propulsion modules – first stage consisting of a large solid PS-1 motor with six solid strap-on boosters, second stage using the Indian Vikas engine which is the Ariane Viking engine made in India under license from SEP – to the maximum extent, GSLV will have a cryogenic third stage with an indigenous engine. Engine, stage development and establishment of test facilities were approved in 1986.

For the GSLV third stage, a 12-ton class cryogenic engine is being proposed. Using a small engine with single element injector, a test facility is operational at Mahendragiri (near Nagercoil, in the south of India), where the main facilities of ISRO Liquid Propulsion Systems Unit (LPSU) are established.

US/Canadian Space Station Pact

Negotiators from NASA and the Canadian Ministry of State for Science and Technology (MOSST) have reached agreement on the text of a memorandum of understanding (MOU) for cooperation in the detailed design, development, operation and utilisation of the international space station.

Negotiators on both sides have now submitted the MOU text to their respective governments for consideration. In Canada, approval of the Cabinet is required. In the US the agreement will be reviewed by both the Executive Branch and the Congress.

Under terms of the new MOU, Canada will provide a mobile servicing system (MSS) to the space station complex. The MSS, an essential part of the station programme will be used in conjunction with the assembly, maintenance and servicing of space station elements. In exchange, Canada will participate in the management and operation of the station, and Canadian users will be able to use the full range of capabilities provided.

China's Practical Payloads

The Ministry of Astronautics in China is developing several spacecraft for practical applications in the field of satellite communications and space remote sensing systems. Long March 2 and 3 vehicles will be used to launch these spacecraft in the next three years:

A possible timetable is as follows:

1988: A Long March 3 vehicle is expected to launch the third geosynchronous communications satellite, a spin-stabilised spacecraft with improved C-band capacity: Long March 2C will also be employed with recoverable capsules for remote sensing operations and for microgravity experiments.

1989: Long March 2C will launch the first Chinese weather satellite into a highly inclined orbit.

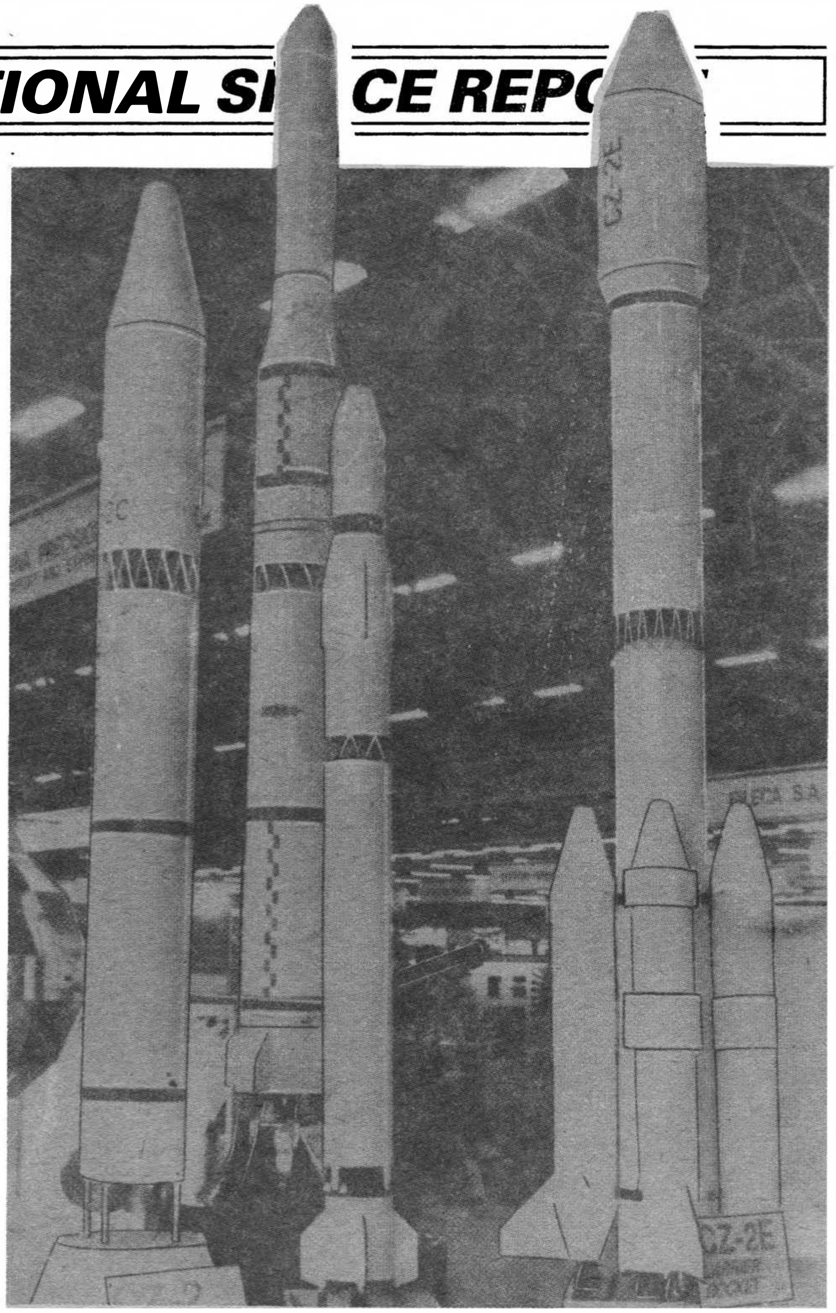
1990: Long March 3 will place in geosynchronous orbit the first Chinese Meteosat-type satellite to reach geosynchronous orbit.

1991: Long March 3A, able to boost 2.5 t in GTO, will launch the first geosynchronous communications/broadcasting satellite of second generation (C-band, 16 available channels, 3-axis stabilisation).

1992: Long March 4, capable of placing 1.5 t in Sun-synchronous orbit, will launch the first Chinese Landsat-type satellite.

New, improved Long March versions, using strap-on liquid boosters on the first stage, are being studied for development by the Chinese Ministry of Astronautics: Long March 2-4L for 9 t in low-Earth orbit, Long March 3A-4L for 4 t to GTO.

The Chinese space industry is looking for every opportunity for foreign assistance and to promote cooperation with developed countries. German research institutes are considering the preparation of a biosatellite with Chinese scientists and specialists; this biosatellite would be based on the recoverable FSW capsule. Canada, with Spar Aerospace, is cooperating in areas of ground station and space systems technology.



The family of Long March launch vehicles being marketed by China Great Wall Industry Corporation *T.Pirard*

Sweden Signs Up with China

The Swedish Space Corporation (SSC) is to combine the scientific Viking and technological Mailstar projects in one single mission, *writes Theo Pirard.*

The new "Freja" project will become the next Swedish star in the sky with the launch assistance of the China Great Wall Industry Corporation (CGWIC) – on November 19, last year, SSC and CGWIC signed an agreement for a firm launch between July and October 1991.

The Freja spacecraft – Freja originates from Scandanavian mythology as the goddess of "fertility" – will weigh 174 kg and orbit at between 1,100 km and 600 km, with 63 to 68 degree inclination. SAAB Space will be prime contractor, with Ericsson and Volvo as main subcontractors.

The Freja mission will consist of:

- A scientific payload for ionospheric measurements and auroral observations.
- An experimental communications payload for store and forward services and Mailstar-type transmissions.

Freja will have two engines to reach its final orbit, instead of using the OTM (Orbital Transfer Module) concept studied by SSC for Chinese Long March 2C operations. The first engine will be used to reach the apogee, while the second would propel the satellite to a higher perigee.

Mir Crew Swap Ends Record Flight

The space mission of Yuri Romanenko and Alexander Alexandrov ended successfully on December 29, 1987 with the parachute touchdown of the Soyuz TM-3 spacecraft capsule in Kazakhstan. Romanenko's record-breaking flight lasted 326d 11h 8m, while Alexandrov logged 160d 7h 17m after replacing Laveikin, who spent 174d 3hr 26m in orbit before his unscheduled return to Earth last July.

Romanenko's smiling appearance and walking ability seen on TV in the days following his return were an indication that the extra three months in space beyond that of previous flights had not resulted in any unexpected ill-effects.

The hope is that muscle wastage, bone calcium loss and other body deteriorations under zero-g will show a levelling off beyond about 200 days in space.

Romanenko's medical condition is therefore of great research interest and is now being studied to provide new information on the effects of long-duration space flight. Such data would be relevant to the planning of a manned Mars mission.

On December 21, 1987, Mir's replacement crew of Vladimir Titov (commander) and Musakhi Manarov (flight engineer) were successfully launched in the three-man Soyuz TM-4 spacecraft and docked with Mir two days later for what is expected to be a year-long stay. Accompanying them was Anatoly Levchenko, identified as a 'researcher', who then joined the returning cosmonaut pair for their re-entry flight and landing seven days later.

It was subsequently revealed that 46 year old Levchenko is considered to be one of the best aircraft test pilots in the USSR with cosmonaut training and that his inclusion in the swap-over procedure was twofold.

First, his presence with the return crew added an extra element of safety in the event that either Romanenko, who would normally have commanded the re-entry, or Alexandrov might have suffered adversely during the descent.

Secondly, according to Vladimir Shatalov, Chief of the Cosmonaut Training Centre at Star City, he participated in order to acquire experience of weightlessness in preparation for later involvement in testing of the Soviet space shuttle that is under development.

Yuri Romanenko preparing space suit during his stay on Mir.

1988 — Year of Promise

This year will be a crucial year for the future of Soviet cosmonautics *writes Theo Pirard.* **A number of major events can be expected during the year:**

1. The giant Energia launch vehicle, which weighs more than 2,000 tons at liftoff, should fly again during the first half of 1988, hopefully to achieve a successful mission with a 100 t payload in low orbit. It is not impossible that Energia, during the second half, could carry a dummy space shuttle mock-up with automated systems to test its avionics. The first flight of the space shuttle with a 2-man crew, including Anatoly Levchenko as a crew member could take place in 1989, depending on the availability and reliability of the Energia carrier.

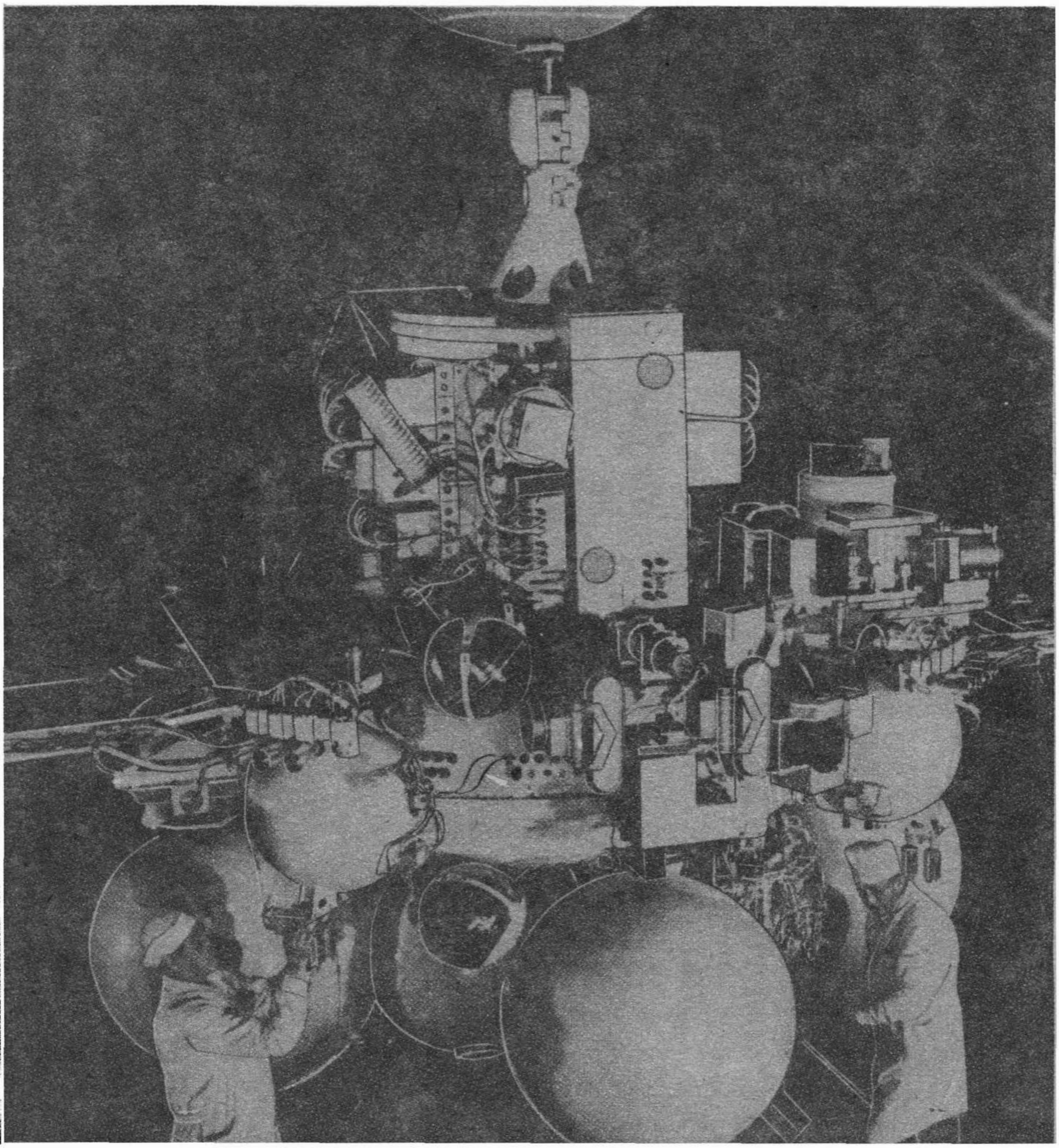
According to the French weekly *Air & Cosmos,* "a prototype of the Russian design, flown by a two man crew, is currently undergoing approach and landing trials on a purpose-built 4.5 km runway at Baikonur; power for these low-altitude tests is provided by four boosters with a total thrust of 36 t; and the two cosmonauts are provided with ejection seats." Cosmonaut Igor Volk has been identified as the chief test pilot for Soviet shuttle flights. Volk, who holds the qualification of "Test-Pilot 1st Class", participated in the Soyuz T-12 mission in July 1984, involving the repaired Salyut 7 station.

2. The international Phobos mission – the most ambitious automated flight of an interplanetary probe – will require two successive Proton launch operations. In early 1987, the Soviet Union had ignition problems with a new Proton upper stage and lost two missions in orbit. Glavcosmos would like to use the Phobos opportunity to demonstrate how reliable the Proton launch vehicle is for space applications.

3. 1988 could be a record launching year for Proton vehicles with possibly one launch per month! Already four planned operations are known: two shots for the Phobos probes, one launch for a Kvant-type module in the latter part of the year, and one launch for the gamma-ray observatory into a highly elliptical orbit.

4. The permanent use of the Mir-Kvant station will continue with regular resupply missions of automated Progress spacecraft. On June 21, a Soviet-Bulgarian crew (consisting of Vladimir Lyakhov, Alexander Serebrov and the Bulgarian Alexander Alexandrov) will begin its flight to Mir-Kvant for a one week stay. Towards the end of 1988, a Soviet-French mission is scheduled to replace Vladimir Titov and Mussa Manarov for one month until the new inhabitants of Mir-Kvant arrive.

INTERNATIONAL SPACE REPORT



Phobos is the irregular and heavily-cratered satellite of Mars, only 21 x 27 km is size, which revolves round the planet in 7.6 hours at a distance of 9700 km. Thought to be a captured asteroid, Phobos probably has a chemical composition characteristic of the early Solar System.

The Soviet Phobos mission involves two identical space probes to be launched in July which, if all goes well, will be in orbits around Mars by January 1989 at an altitude that is initially slightly above that of Phobos.

Detailed investigations of the surface of Phobos are planned by international teams of experimenters and have already been reported by *Spaceflight* in 1986 (p.113 and 348) and 1987 (p.55). Two types of investigation are involved.

One is by robotic landers, two of which will be carried by each spacecraft, and the second is by remote-sensing probes as the spacecraft skim past Phobos at a distance of only 30-80m under automatic radar control.

One lander is a static observatory designed to return a year's data and the second is a smaller lander designed to hop around Phobos' low-gravity suface in kangeroo-like hops. Each fly-by will last about 15 minutes during which remote-sensing techniques will enable chemical compositions to be determined.

TV cameras are to play a major role in relaying back to Earth the interception of Phobos and subsequent surveys of the Moon. Mars will also be surveyed for suitable landing sites for future missions. A record number of 31 experiments is planned, and the mission is seen as a forerunner to the surface exploration of Mars by robots in the 1990s.

'Honour' for IRAS Satellite

The Smithsonian Institution National Air and Space Museum, Washington, has installed a full-scale replica of the Infrared Astronomical Satellite (IRAS) in its Star Gallery. It accompanies an exhibit on the many findings of IRAS and the applications of infrared astronomy.

IRAS was in orbit for 10 months in 1983. During that period, it returned so much information that much of it is still being sorted out. Among its findings were a quarter-million sources of infrared radiation, the first comet ever discovered by a satellite and 10,000 galaxies never before seen.

The satellite surveyed 95 per cent of the sky in each of four infrared bands. It provided a much better view of the infrared portion of the spectrum than is possible with gound telescopes or airplanes.

IRAS stopped transmitting when it ran out of coolant, which kept the sensitive telescope at a temperature of −271 C. The satellite was a joint project of NASA, the British Science and Engineering Research Council (SERC) and the Netherlands Aerospace Agency (NIVR).

The model is a full-size reconstruction built from back-up, left over and new components, and the exhibit is titled "A Telescope in a Bottle", a reference to the thermos bottle-like cooling system. Also included is a mosaic depicting an infrared view of the Milky Way.

SATELLITE DIGEST – 209

Robert D. Christy

Continued from the January 1988 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1889, 1987-85A, 18394

Launched: 0830, 9 October 1987 from Tyuratam by A-2.

Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.

Mission: Military photo-reconnaissance, recovered after 14 days.

Orbit: 348 x 415 km, 92.21 min, 69.99 deg.

COSMOS 1890, 1987-86A, 18397

Launched: 2148, 10 October 1987 from Tyuratam by F-1.

Spacecraft data: Cylindrical, probably about 7 m long and 2 m diameter, equipped with solar cell panels and with a mass around 5000 kg.

Mission: Electronic intelligence gathering over ocean areas.

Orbit: 403 x 417 km, 92.78 min, 65.01 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1891, 1987-87A, 18402.

Launched: 1235, 14 October 1987 from Plesetsk by C-1.

Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.

Mission: Navigation satellite.

Orbit: 953 x 1028 km, 104.98 min, 82.93 deg.

COSMOS 1892, 1987-88A, 18421

Launched: 0910, 20 October 1987 from Plesetsk, by F-2.

Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.

Mission: Electronic intelligence gathering.

Orbit: 635 x 665 km, 97.79 min, 82.52 deg.

COSMOS 1893, 1987-89A, 18432.

Launched: 1425, 22 October 1987 from Plesetsk by A-2.

Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.

Mission: Military photo-reconnaissance over an extended period.

Orbit: 165 x 352 km, 89.70 min, 67.17 deg, manoeuvrable.

USA 27, 1987-90A, 18441

Launched: 2132, 26 October 1987 from Vandenberg by Titan 34D.

Spacecraft data: KH-11 type, military reconnaissance satellite. The length is about 15 m, maximum diameter 3 m and the mass around 13 tonnes.

Mission: Military photo-reconnaissance, returning photographs via a television-type transmission system.

Orbit: Approximately 265 x 500 km, 92.2 min, 97.0 deg, manoeuvrable.

COSMOS 1894, 1987-91A, 18443.

Launched: 1515, 28 October 19897 from Tyuratam by D-1-e.

Spacecraft data: Stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.

Mission: Luch-type data-relay and communications satellite. It may also be providing tracking support to Earth orbiting spacecraft by providing radio coverage while they are out of communication with normal ground stations.

Orbit: Geosynchronous above 24.5 deg west.

COSMOS 1895, 1987-92A, 18491.

Launched: 0905, 11 November 1987 from Tyuratam by A-2

Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit

US Remote Sensing Needs More Funds

Funds for NASA projects involving remote sensing of the biosphere are "woefully inadequate," according to a study done for NASA by the Space Science Board (SSB) of the National Research Council. The board concluded that developments in remote sensing and computer technology now make an integrated study of the biosphere truly possible for the first time, *writes Jim Sweeney.*

Data handling and storage is the weak link and the SSB says the majority of the problems are political, not technological, with the most important factor being a commitment by NASA and the US government overall to the long-term continuity of remote sensing data.

NASA is in a unique position to oversee the development of biospheric sciences, the SSB says, and the agency needs a research programme in that field. Both basic biospheric sciences and ecological theory are in their youth. Estimates of the number of species on the planet, for example, range from three to 10 million.

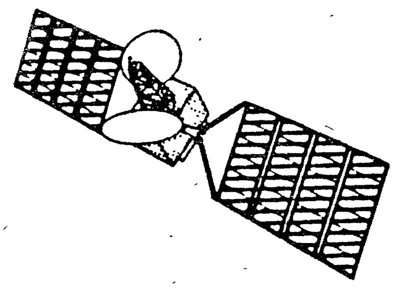
The board warns that remote sensing will create a data base management challenge, and new systems must be developed to aid the integration of different kinds of data, taken at different spatial and temporal scales. Equally important is a network to link scientists in the US and other countries with the data bases.

The board criticised the US government for putting more resources into developing and launching satellites than into providing for the processing, archiving, distribution and analysis of the data produced. Furthermore, funding for basic and applied remote sensing research at NASA centres and universities "has been reduced to a level where the nation stands to lose a major analytical capability".

Many scientists have expressed concern that commercialisation of the US land observing satellite programme will kill the land resources remote sensing programme. Commercialisation could slow access to data, and the SSB urged that satellites not be turned over to the private sector. The rate at which biospheric science develops "will be strongly dependent upon the ability of scientists working in the field to have access to the data and data bases they require".

The SSB study identified several crucial requirements for a program of remote sensing of the biosphere:

- **Maintain existing satellite systems.** Landsat and other systems that acquire data in the visible and thermal infrared portions of the spectrum must be maintained for the next decade to provide continuity of data. The board said it is "imperative" that the Landsat thematic mapper sensors be maintained. Also, more advanced sensors should be developed.
- **Aircraft remote sensing.** More work needs to be done with aircraft remote sensing. Existing aircraft sensing systems are essential for photographic and multispectral sensor systems. Remote sensing from space can not replace all other methods of observation, the board notes, but direct measurement and acoustic remote sensing are needed in ocean studies because the ocean is effectively opaque to electromagnetic radiation. Aircraft also have much more scheduling and flight path flexibility than satellites.
- **Advanced microwave devices.** Active microwave devices have "considerable potential", the board concluded. They can see through cloud cover, penetrate deeper into vegetation canopies, detect higher leaf area indices than other sensing devices and can detect directly total biomass and water content of terrestrial vegetation. Experiments with active microwave devices on the space shuttle demonstrated the potential to detect subsurface drainage patterns in desert areas.



containing batteries, control equipment and rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 15 days.
Orbit: 227 x 286 km, 89.67 min, 70.36 deg.

COSMOS 1896, 1987-93A, 18535.
Launched: 0930, 14 November 1987 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical, camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Orbit: 208 x 266 km, 89.25 min, 64.80 deg, manoeuvrable.

UPDATES:

1977-102A&B, ISEE 1&2 decayed simultaneously on 26 September 1987 after 3626 days.
1983-110A, COSMOS 1507 decayed on 19 August 1987 after 1390 days.
1985-114B, USA-14 decayed on 9 August 1987 after 604 days.
1986-102A, COSMOS 1731 decayed on 11 September 1987 after 259 days.

X-ray Astrophysics Facility

NASA's Marshall Space Flight Center released a request for proposal to select a prime contractor for the long duration, human-tended satellite called the Advanced X-Ray Astrophysics Facility (AXAF), *writes Roelof L. Schuiling.*

The results of earlier X-Ray satellites such as Uhuru and HEAO-2 were so valuable that astronomers recommended the establishment of a long duration X-Ray facility in space. In addition to AXAF's value in astronomical studies, it will also be an important new tool for basic research in plasma physics, the fundamental properties of matter and the laws of physics.

Once in orbit the AXAF will join the Hubble Space Telescope and the Gamma Ray Observatory as the third in the series of "Great Observatories" planned to provide astronomers with on-orbit facilities for long duration study. Periodic maintenance and repair for AXAF will be done by crews of either the space shuttle or the space station.

The industry candidates for this program are Lockheed Missiles and Space Co. and TRW Inc. If funding and authorisation for the AXAF are received this year, the satellite could be launched in 1995.

Ocean Theory for Early Venus

Venus may have once had hot, planet-spanning oceans for hundreds of millions of years, according to a new planet evolution theory and NASA spacecraft data.

The new history for Earth's twin planet could solve several Venus mysteries and explain many of the extreme conditions found on Venus today.

Called the 'wet greenhouse' theory, the explanation was developed by Drs. James Kasting, Tom Ackerman and James Pollack, of NASA's Ames Research Center.

The 'wet greenhouse' theory can be used to account for the first time for the almost completely waterless state of the present-day planet and as an explanation of where the planet's mission oxygen is stored.

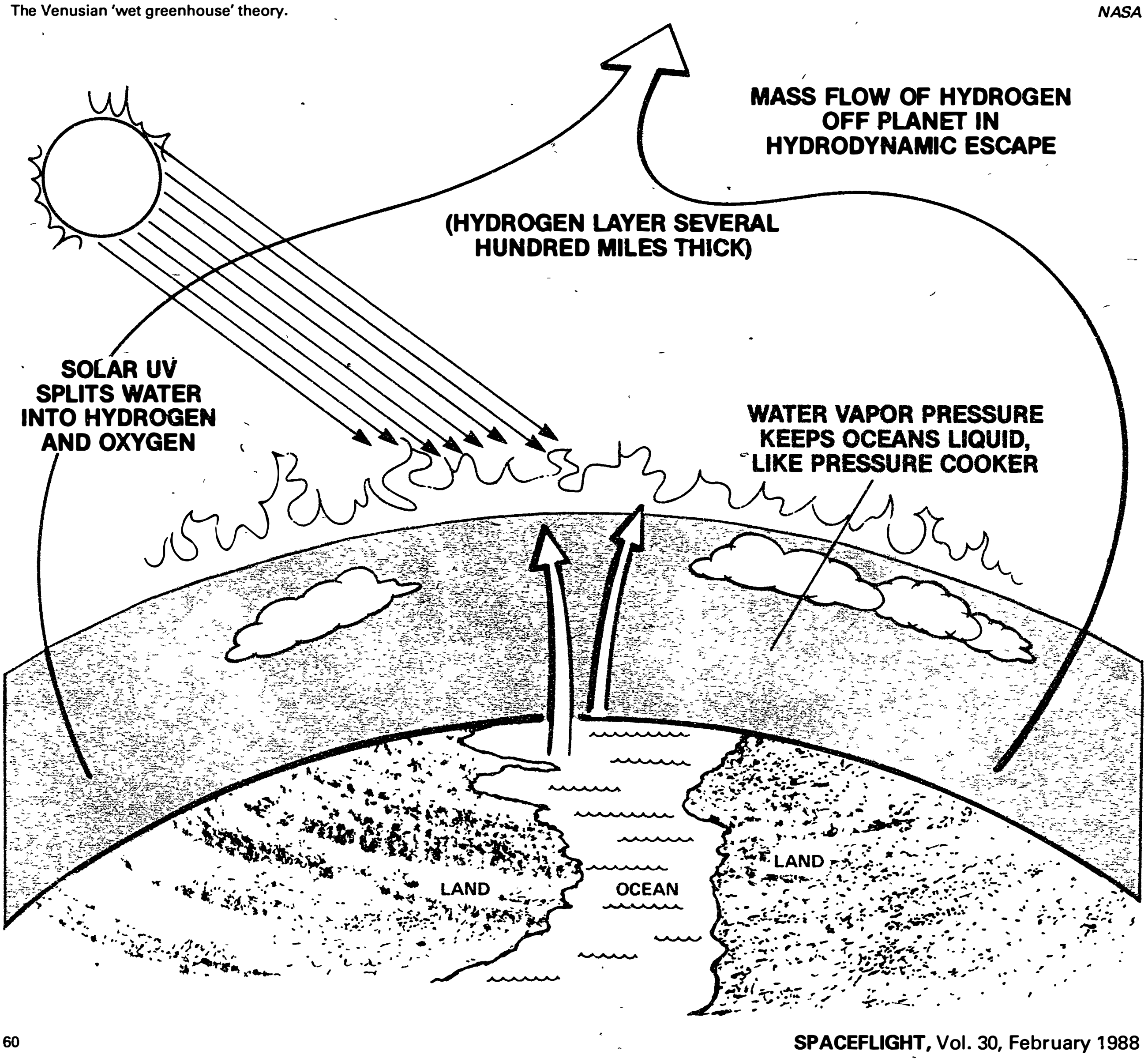
Ironically, the presence of early oceans on Venus may well account for the incredibly dry condition of today's planet.

Venus today is totally dry with a surface temperature hotter than the melting point of zinc (800 degrees F) and an enormously heavy, largely carbon dioxide atmosphere, 100 times as dense as Earth's.

The planet's original atmosphere – of about four billion years ago – is believed to have been much like Venus's atmosphere today: many times denser than Earth's and mostly carbon dioxide.

Dr. Kasting's 'wet greenhouse' theory suggests that this enormous primordial atmosphere was subsequently reduced to a small part of its original mass by ocean-planet interactions, leaving an atmosphere about the same size as Earth's. The thin Earth-like atmosphere then lasted several hundred million years. Eventual loss of most of the water would have stripped

The Venusian 'wet greenhouse' theory. *NASA*



the planet of its water, leaving it bone dry as Venus is today.

By contrast, the currently-accepted 'runaway greenhouse' theory assumes the continuous presence of an extremely heavy atmosphere. Loss of the same proportion of water from this atmosphere still leaves us with far too much water – 100 to 1,000 times what we actually find on Venus.

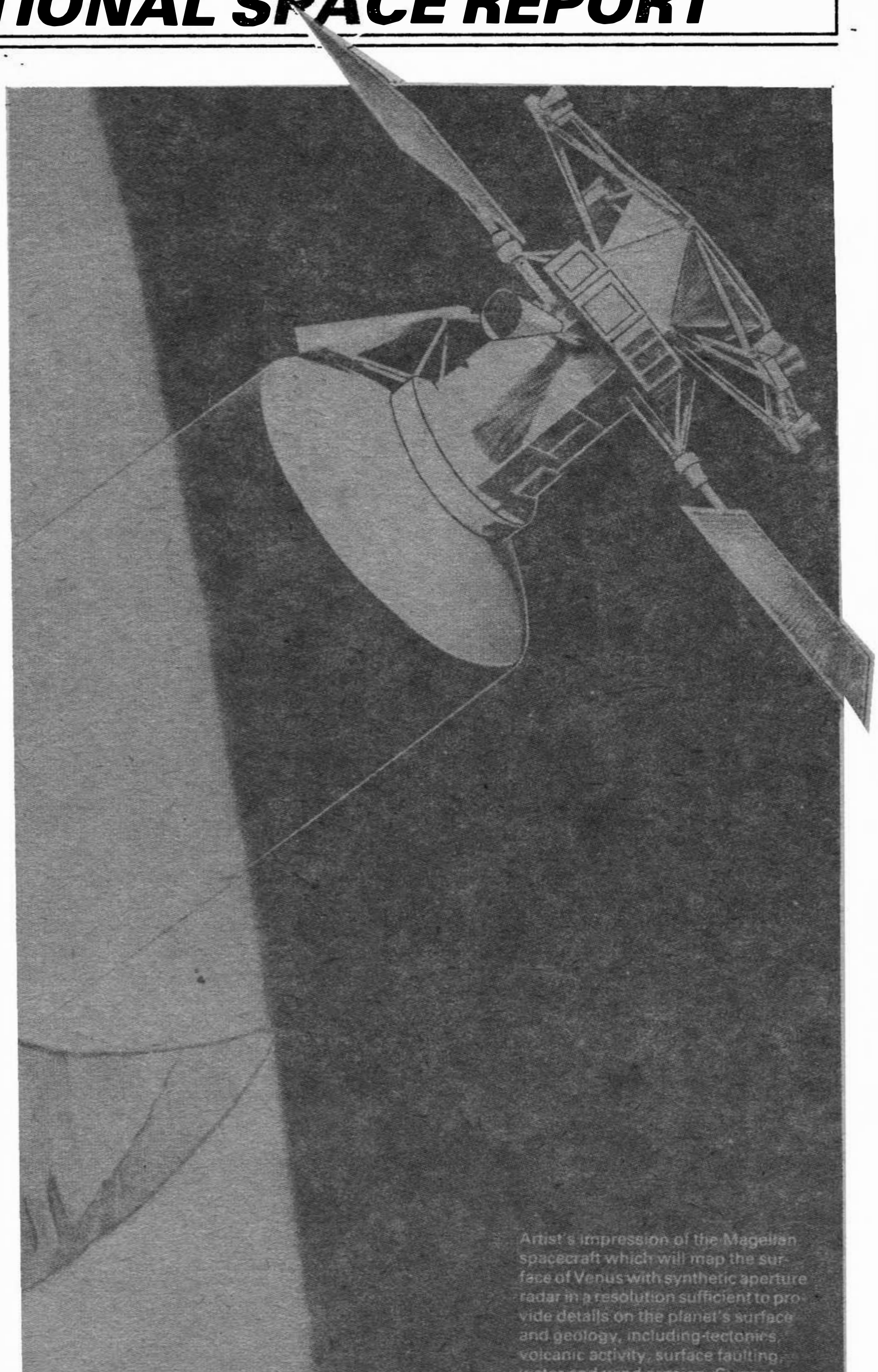
In the runaway greenhouse, Venus's huge primordial atmosphere would have trapped much of the Sun's heat, preventing formation of any oceans at all, and creating a dense water vapour-carbon dioxide atmosphere. An immense amount of water vapour would have risen to the top of the atmosphere and solar ultraviolet radiation would have split (dissociated) the water molecules into hydrogen and oxygen with the hydrogen being blown away to space by hydrodynamic escape processes.

The hydrodynamic escape would have stopped when water was reduced to a minor constituent of the atmosphere (around 20 per cent). However, even 20 per cent of an enormous atmosphere like Venus's is still a lot of water, and much of this water should be left on the planet today – but the four atmosphere probes of NASA's Pioneer-Venus spacecraft didn't find it there.

According to the 'wet greenhouse' theory, Venus formed with plenty of original water which condensed out and created Earth-scale oceans. The oceans were hot, due to the planet's closeness to the Sun and the trapping of incoming solar heat by atmospheric carbon dioxide and water vapour, and much of the oceans evaporated until perhaps 50 per cent of the atmosphere was water vapour. However, at this point water vapour pressure had built up so that it prevented further evaporation from the oceans.

The oceans were very hot, 200-300 degrees F, yet because of the high pressure of atmospheric water vapour, the bulk of the water on the planet remained liquid. Hydrogen would still have escaped rapidly from the top of the atmosphere by the hydrodynamic escape mechanism and the atmospheric water lost this way would have been steadily replenished by further evaporation from the underlying ocean.

By remaining liquid over millions of years, the oceans were able to move the original huge mass of carbon dioxide gas out of the atmosphere by converting most of this gas into carbonate rocks in Venus's crust. This process (generally described as "weathering") reduced the atmospheric density on Venus from perhaps 90 times Earth's atmosphere to perhaps only about the same density as Earth's atmosphere.



Artist's impression of the Magellan spacecraft which will map the surface of Venus with synthetic aperture radar in a resolution sufficient to provide details on the planet's surface and geology, including tectonics, volcanic activity, surface faulting, water and wind erosion. Current plans are for arrival at Venus in 1990.
Martin Marietta

In both greenhouse theories, when water vapour dropped to around 20 per cent of the atmosphere, hydrodynamic escape ceased to push hydrogen off the planet, and destroy its water.

But 20 per cent of a thin Earth-size atmosphere is about 100 times less water than 20 per cent of an enormous, Venus-type carbon dioxide atmosphere. According to the wet greenhouse model, by the time hydrodynamic escape had ended, with its thin Venus atmosphere, nearly all of Venus's water was lost. Slower hydrogen processes in the several billion years since then have reduced the planet's water still further to today's tiny amount.

Most scientists believe Venus originally had water because Earth and Mars have abundant water (Mars' water is frozen), and formation conditions of all three planets were similar. The building blocks of all three were dust and ice grains circulating freely in the interstellar gas gloud that formed the Solar System and these primordial materials are believed to have been reasonably well mixed in a very wide inner-planet region.

Mercury Orbiter

A resurgence of scientific interest in the planet Mercury has become apparent in recent years. After the lapse of more than a decade, a meeting devoted exclusively to Mercury was held in the summer of 1986 in Tucson, Arizona and was attended by over 100 scientists. There was a session on Mercury at the Spring 1987 meeting in Baltimore of the American Geophysical Union. In addition, the need for a Mercury Orbiter was recognised in 1986, in separate actions, by the US Space Science Advisory Board (of the National Academy of Sciences) and the European Space Agency. To provide continuity for Mercury studies and advocacy, a Mercury Consortium has been established by a group of scientists after discussions at the Lunar and Planetary Science Conference in March 1987.

This renewal of attention almost 15 years after the three flybys of Mercury by Mariner 10 is a result of scientific and engineering reasons. Scientifically, re-evaluation of the Mariner 10 data and new ground-based observations (radar studies of the surface and discovery of a tenuous sodium/potassium atmosphere) combine with the recognised importance of Mercury as one key to the origin of the Solar System to kindle enthusiasm for additional observations and analyses. The engineering feasibility of a Mercury Orbiter, the prime tool for future studies, has been advanced significantly by the discovery of a new class of gravity-assist trajectories to the planet and the availability of thermal shielding technology for extended operations so close to the Sun.

The first impression of Mercury, upon looking at the images taken by Mariner 10, is that it is very much like the Moon, with a heavily cratered surface. Indeed, there are similarities, but the differences are significant. Perhaps the most striking feature of the planet is the probable presence of an enormous iron core; it spans 75 per cent of Mercury's diameter and gives it an average density comparable to that of Earth and over 60 per cent greater than the density of the Moon.

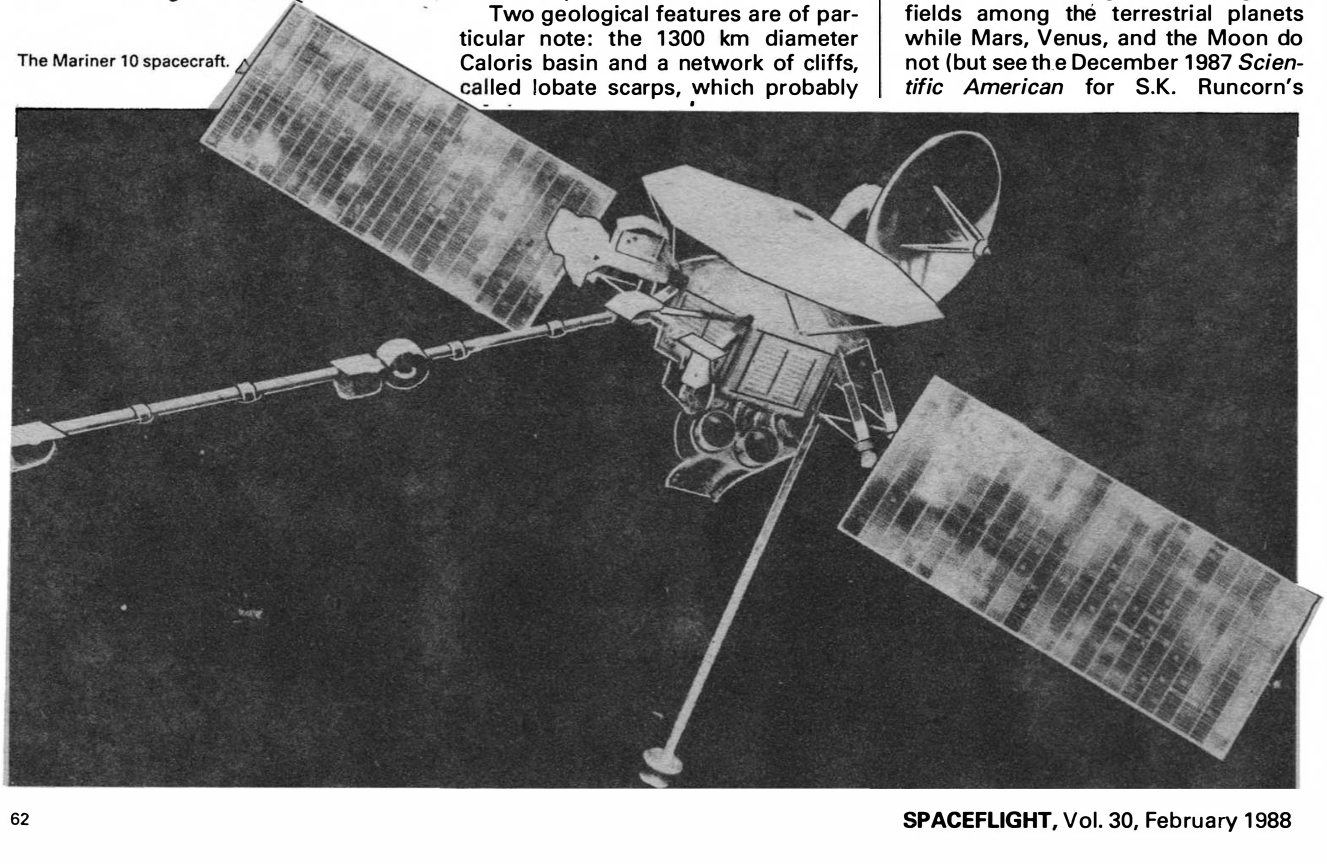
Two geological features are of particular note: the 1300 km diameter Caloris basin and a network of cliffs, called lobate scarps, which probably envelops the entire surface (Mariner 10 only imaged 45 per cent of the surface).

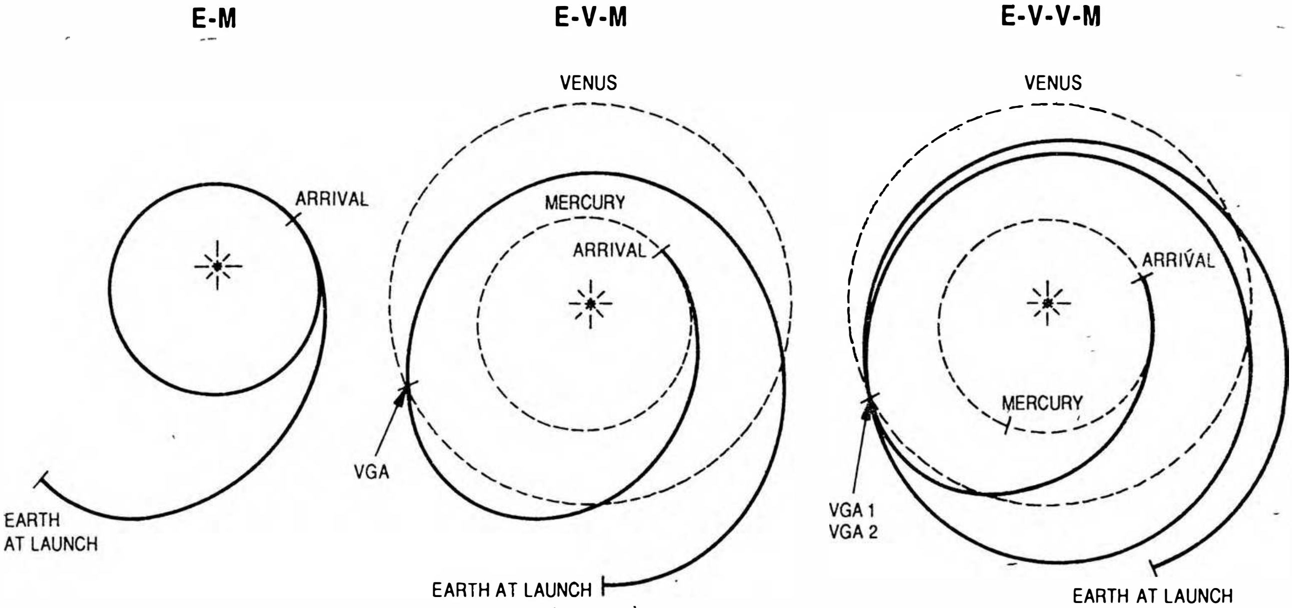
The Caloris basin was created approximately four thousand million years ago when a large body impacted Mercury. The trauma induced by this event is represented not only by the basin itself but also by extensive ejecta deposited over two thousand kilometres distant and features created at the opposite point on the planet by converging seismic waves.

Cliffs that wind hundreds of kilometres over the surface of Mercury were formed from crustal forces generated by a period of global contraction which may have resulted in a shrinkage of the planetary diameter by several kilometres. These lobate scarps average a kilometre in height and have a rounded, lobed appearance, hence their name.

One of the surprises generated by the Mariner 10 flyby was the discovery of an appreciable magnetic field and, hence, complex interaction of the planet with the solar wind. Mercury and Earth have significant magnetic fields among the terrestrial planets while Mars, Venus, and the Moon do not (but see the December 1987 *Scientific American* for S.K. Runcorn's

The Mariner 10 spacecraft.





Three possible trajectories going from Earth to Mercury. The trajectories utilising gravity assists from Venus and Mercury require less propulsive capability per kilogram of mass delivered into Mercury orbit. Multiple encounters (not shown) with Mercury increase delivery capability even further. *NASA/JPL*

hypothesis of an ancient, strong magnetic field for the Moon). The three gas giants visited to date by spacecraft have fields, while a determination for Neptune must await the August 1989 flyby of Voyager 2.

To read the final chapter of Robert G. Strom's book, *Mercury: The Elusive Planet* (Smithsonian Institution Press, 1987), is a revelatory experience: the history of a world is recited, albeit with many partially finished chapters. Strom is a member of the Mercury Consortium and has skillfully presented current knowledge of the planet, largely based upon Mariner 10 data.

Mariner 10 is somewhat of a legend around JPL. It was accomplished with an expenditure of an economical $98 million and visited Venus once and Mercury three times before the spacecraft finally exhausted its supply of attitude-control gas. Flight engineers had to cope with a seemingly endless series of hardware problems: malfunctioning camera heaters, an erratic antenna feed system, computer troubles, primary power system failure, accidental loss of some attitude-control gas, tape recorder failure, loss of several telemetry channels, and more! But the combination of human and machine prevailed.

One of the most challenging engineering problems was occasioned by the low supply of attitude-control gas after inadvertent losses. "Solar sailing" was devised as a counter-measure. By continually adjusting the orientation of the spacecraft's solar panels, solar photon pressure was utilised in a constructive fashion to help control the attitude of the spacecraft, thus reducing its reliance on gas expulsions.

Closest approach to Venus took place on Feburary 5, 1974, three months after launch, an event of obvious scientific importance and the first use of a planetary gravity assist, and the craft sped on its way to the Mercury I encounter on March 29, 1974. Mercury II (September 21, 1974) extended imaging of the surface to the south polar region.

The concept of multiple encounters with Mercury through orbital phasing was due to the late Professor Giuseppe Colombo of Padua (see the July-August 1984 edition of this column), but with attitude-control gas running out, Mercury III was in doubt.

To conserve that precious commodity, the flight team continued the practice of solar sailing and also allowed the spacecraft to turn slowly about its roll axis, rather than expend gas to control it. Your correspondent played a minor role in the drama by designing and directing a change in JPL's computer program for trajectory calculations in order to account for accelerations induced by the new geometry. Though the role was minor, the concomitant excitement was major. Shamelessly trading on my new association with the Mariner 10 project (I had been working on trajectory software for the Viking project), I waited on March 16, 1975 in the control centre with the navigation team as the time for closest approach drew near. Suspense was engendered

A transition from heavily cratered terrain to a smooth plain, the latter thought to be of volcanic origin, is visible in this Mariner 10 photograph of Mercury taken from 34,860 miles in March 1974. *JPL*

because there was a moderately large probability that the spacecraft would impact the planet due to trajectory dispersions. There was no planetary quarantine for Mercury, but some scientific data would be lost. The clock advanced toward the time of closest approach. People joked and looked at telemetry, which would cease in case of impact. The time of potential crisis came at Mercury, but we had to wait an additional nine minutes for the signal, or its lack, to reach Earth. The flyby was, of course, completely successful with the spacecraft passing a healthy 327 km over the planetary surface, but I can still recall the tension of watching the sweep of the second hand and waiting for a possible silencing of communications. The attitude-control gas was depleted one week later, ending the mission and illustrating the slim thread by which the success of Mercury III hung.

What are the prospects for the future exploration of Mercury? There is no planned mission on the books, and one is not likely before the second half of the next decade, but, as mentioned above, scientific interest is high and the Solar System Exploration Division of NASA has been briefed on a Mercury Orbiter mission.

It was formerly believed that a mission to orbit Mercury would probably require advanced propulsion systems such as solar (or nuclear) electric propulsion or solar sails (for the last possibility, see the paper by French and Wright in the December 1987 ***JBIS***). In 1985, Dr. Chen-wan Yen of JPL showed how Mercury itself could be used, through multiple swingbys prior to insertion into orbit, to subtract energy from the incoming spacecraft in order to reduce reliance on onboard propulsion systems. Travelling to Mercury poses the opposite problem of a trip to the outer planets, where energy must be added to the spacecraft.

Consider, for example a spacecraft launched in July 1996 with a Titan IV/Centaur G-prime system and which mades two (gravity assist) swingbys of Venus and one of Mercury, before burning its motor to go into a 300 km circular orbit about the inner planet: a 612 kg orbiter can be delivered in this fashion. The efficiency of the Mercury swingbys is seen through the datum that mass-to-orbit is increased to 976 kg by a second Mercury swingby and 1209 kg for a third swingby. The flight times from Earth to Mercury orbit are 2.9, 3.8, and 5.3 years, respectively, for these three options.

One legacy from Mariner 10 was the demonstration that persistence could literally reveal to us a new world. Copious quantities of the virtue will be needed to bring us back to the iron planet, but a good start has been made.

Keck Telescope Progress

It was like being transported into the past by a time machine when I walked into the headquarters of the California Association for Research in Astronomy (CARA) in Pasadena, across the street from the main Caltech campus. The first step was of only a few years; I had come to talk with Bill Irace, the Project Engineer for the Keck Telescope, and he and I were former colleagues on the Infrared Astronomical Satellite flown in 1983. But the second step covered almost a century, encompassing the days of the great California telescope builders: the 36-inch refractor at Lick Observatory (1888); the 60 inch (1908) and 100 inch (1917) Mount Wilson reflectors; the 200 inch Hale reflector (1948) – all were the largest in the world in their time. The CARA headquarters itself is located in a fine old house, remodeled to accommodate offices. The ten-meter (396 inch) Keck Telescope is scheduled to become operative in 1991 and in counterpoint to its historical roots is distinctly an instrument of the future. The largest optical telescope in the world, it will incorporate some of the most advanced technology ever devised for an astronomical facility.

The largest diameter mirror in astronomical use today is the six-metre glass giant within a Soviet telescope in the Caucasus mountains. This telescope has not yet lived up to expectations (but see a set of photographs in the August 1987 *Sky and Telescope*), and the five-metre Hale Telescope on Mount Palomar remains the world's premier large telescope. The Palomar and Soviet telescopes each employ monolithic mirrors to collect light from celestial sources. It is difficult to build mirrors much larger than these, so the Keck Telescope will employ 36 hexagonal mirrors, each with a (maximum) diameter of 1.8 m, as constituents in the mosiac comprising the primary.

Two technical challenges face one who would produce a segmented mirror (see the June 1985 and January 1986 editions of this column for additional discussion). First, the individual mirror segments must be shaped with non-traditional techniques because they obviously cannot be axially symmetric. Second, the orientations of each of the small mirrors must be accurately controlled so that the synthesised image will be sharp.

The project scientist, Dr. Jerry Nelson of the University of California at Berkeley, led the initial design and development of methods for shaping and control of segmented mirrors.

The idea underlying the shaping process for a mirror segment is to stress the edges of the mirror blank in such a way as to allow it to be ground by traditional techniques into a spheroidal surface. Then, upon completion of grinding and release of the stress points, the mirror elastically relaxes into its correct, more geometrically complex shape. The key, of course, is to have stressed the mirror in a fashion that yields the desired shape after the post-grinding transformation.

A present, the first few mirrors have been stress polished at Itek Optical Systems in Lexington, Massachusetts, and the products are being tested and cut into hexagons. The final precise shape will be achieved through some combination of computer-guided polishing and the use of warping harnesses for deformation.

The 36 mirror segments will be supplemented by six spares. The number of spares is dictated by the symmetry of the primary which is composed of six types (surface figures) of six mirrors per type. The material used by the mirror manufacturer is a glass-ceramic called "Zerodur". The Schott Glassworks in Mainz, Germany has developed a material which is part glass and part ceramic. The crystalline ceramic and the glass have temperature responses which nearly cancel one another, producing a mirror which is 100 times more stable under temperature variation than the Pyrex glass from which the Palomar mirror is made and five times better than fused quartz (which was used in the 3.8 m Mayall Telescope at Kitt Peak).

The payoff from the segmented mirror design is realised in the light weight of the structure, 13.1 metric tons, compared with 37 tons for the Soviet 6m. telescope's main mirror. No monolithic structure could adquately support itself with the thickness of 7.5 cm which characterises the Keck mirror.

Once in place, the segmented mirror must behave as if it were, in fact, a monolithic structure. This, the second principal design challenge that faced Nelson and his colleagues, was answered by developing two systems of support for each individual mirror segment: a passive system and an active system.

The passive support system consists of a flex disk imbedded in the back of each mirror segment and 36 support points, also in the rear. The flex disk responds to forces in the plane of the mirror, while the support points are effective in controlling motion perpendicular to the plane. It is expected that those passive support systems will never require maintenance or replacement.

The active control system employs two sensors mounted along each seam between mirror segments (a 3 mm gap

separates segments). The function of the sensors is to measure the relative positions (to within 1.5 nanometers) of the mirror edges and hence allow adjustment on a segment-by-segment basis. The actuators which accomplish this adjustment are capable of moving the mirror segment in steps as small as four nanometers. The wavelength of visible light is greater than 400 nanometers.

The telescope structure containing the mirror will be articulated by means of an alt-azimuth mount which rides on four oil bearings and is turned by small friction-drive motors. Ease of operation will be promoted by a modular design to facilitate reconfiguration of the telescope for differing observational needs. When the tube is rotated to the horizontal position, the "payloads" in the two modules, one in the front and one in the rear end, can be easily changed. For example, a Cassegrain secondary mirror might be placed in the front module and a flat mirror, at a 45 degree angle to the axis of the tube, in the rear module. The flat mirror allows the beam of light to be directed to instruments on a circumscribed observing (Nasmyth) platform after reflection from the primary and secondary mirrors.

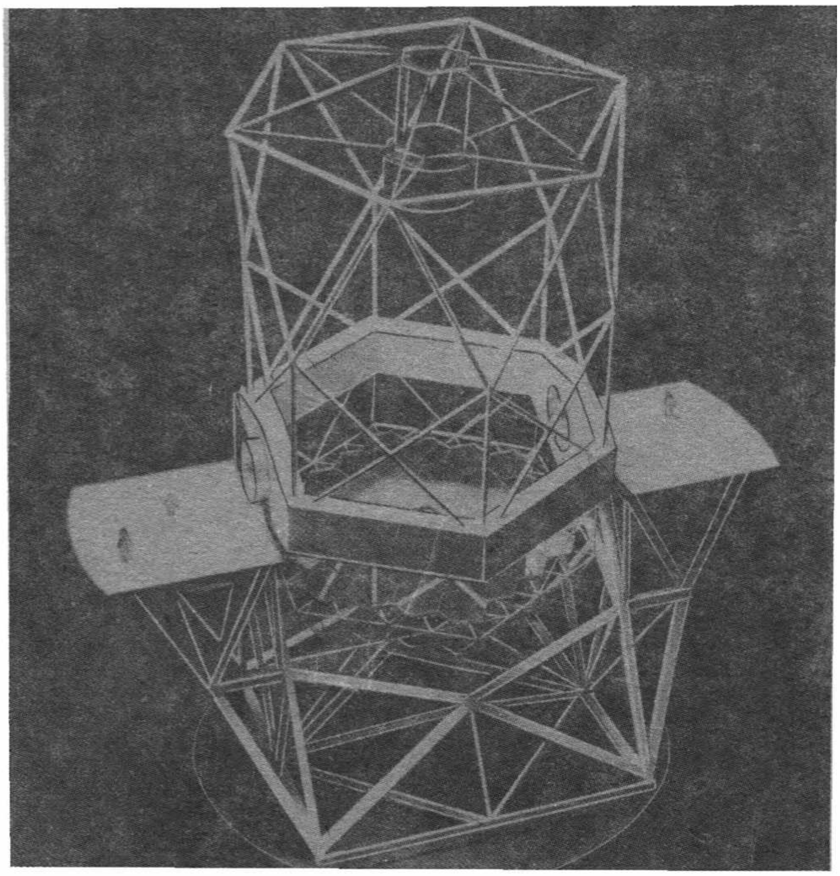
Up to six such instruments can be serviced by the flat mirror during a single observing session. Two principal platform locations will be devoted to spectrometers of up to ten tons while the other four positions hold smaller devices.

The Cassegrain secondary in the front module may be replaced by a (chopping) secondary for infrared work, and the rear module may accommodate several infrared instruments with their cooling dewars, each accessible during a single observing session via a flat mirror "switch".

The California Association for Research in Astronomy is a non-profit corporation formed by the University of California and the California Institute of Technology ("Caltech", the parent organisation of JPL) as equal partners. Caltech is funding the construction of the observatory, estimated at $87 million, utilising a $70 million grant from the W.M. Keck foundation. The University of California will supply operating funds for 25 years, which amount to a sum approximately equal to the Caltech contribution. Astronomers from both universities will share equally in observing time, and the University of Hawaii will also have access to the telescope since it provided the observing site.

The Board of Directors of CARA maintains overall supervision of the Keck Observatory project. The Project Manager is Gerald M. Smith, who served as manager for the Infrared Astronomical Satellite in 1982-83.

Construction of the observatory on Mauna Kea, the highest point in the Pacific at 4205 m, is underway. Sixty metres below the peak of this dormant volcano the Keck instrument will join several other large telescopes which inhabit the most valuable piece of sub-orbital astronomical real estate in the world. Although Mauna Kea did erupt about 4000 years ago, the slow drift of the Hawaiian islands to the northwest has removed Mauna Kea from likely connection to its source of magma.



Model of the Keck 10 metre telescope. *Caltech*

The same thin air that provides excellent observing conditions – a typical stellar image is about one-half second of arc in diameter compared to one second of arc at lower sites – poses a hardship for resident astronomers. Before an observing session, astronomers become acclimatised by staying overnight at the Hale Pohaku dormitory facility, located at 2800 m elevation on the mountain. Emergency oxygen supplies are kept available at the observatory in case of altitude sickness, and portions of the observatory may be boosted with supplemental oxygen for human comfort. Some observers may operate the telescope remotely from observatory headquarters in Kamuela (Waimea) by means of an electonic link.

A five-mile radius about the peak delimits the Mauna Kea Science Reserve which provides a buffer zone for undisturbed astronomical activities.

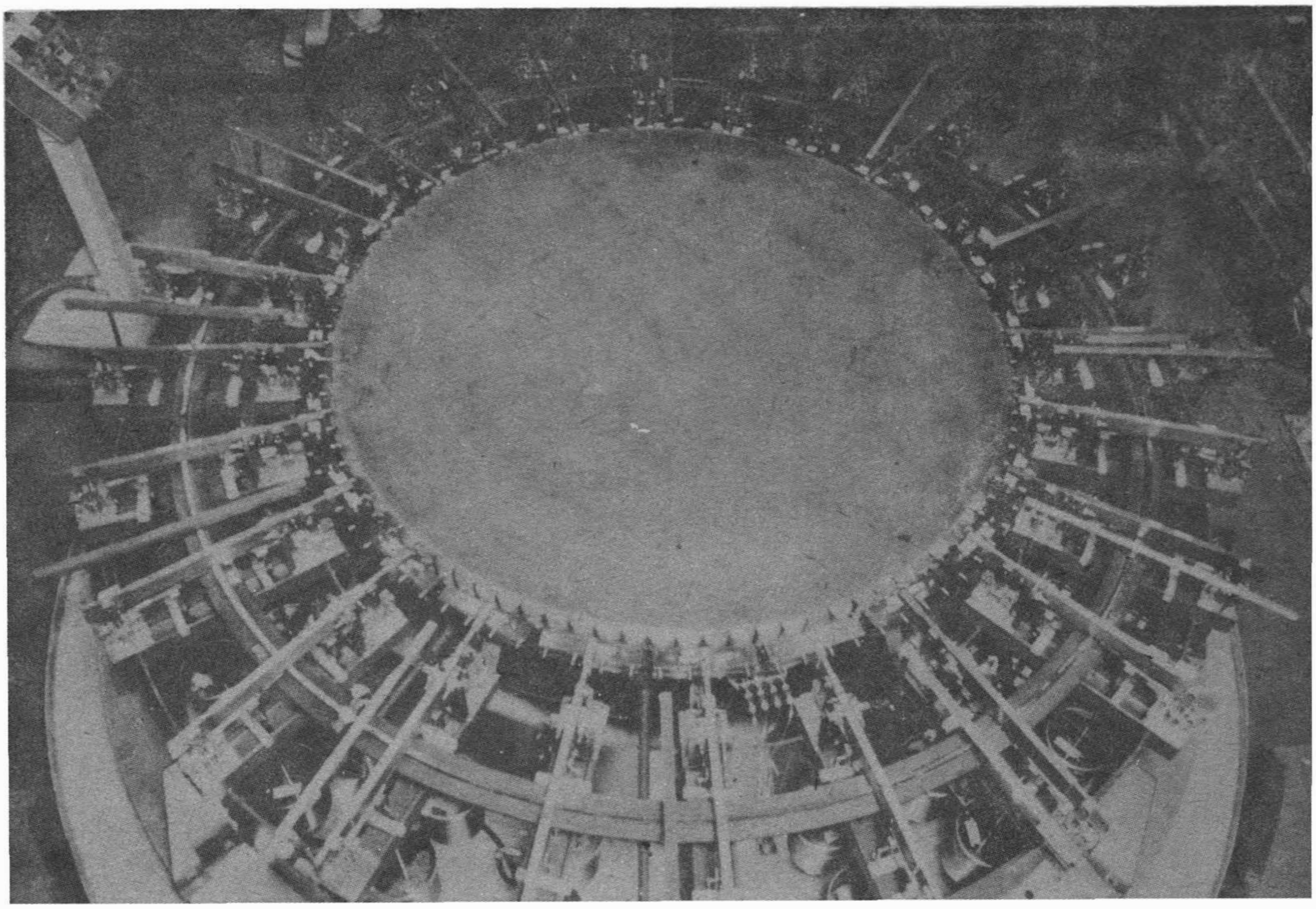
The scientific bonanza which will come from the world's most powerful optical and infrared telescope flows from the central problems of modern astronomy.

The metaphor of a time machine is most apt for a large-aperture telescope. Reaching thousands of millions of light years into space, the Keck Telescope will permit observations of conditions when the universe was much younger; one can then address questions concerning the evolution and clustering of galaxies.

Spectroscopy proceeds by spreading light over a range of wavelengths and hence requires an abundance of photons to be effective, a collection task for which the Keck Telescope is quintessentially suited.

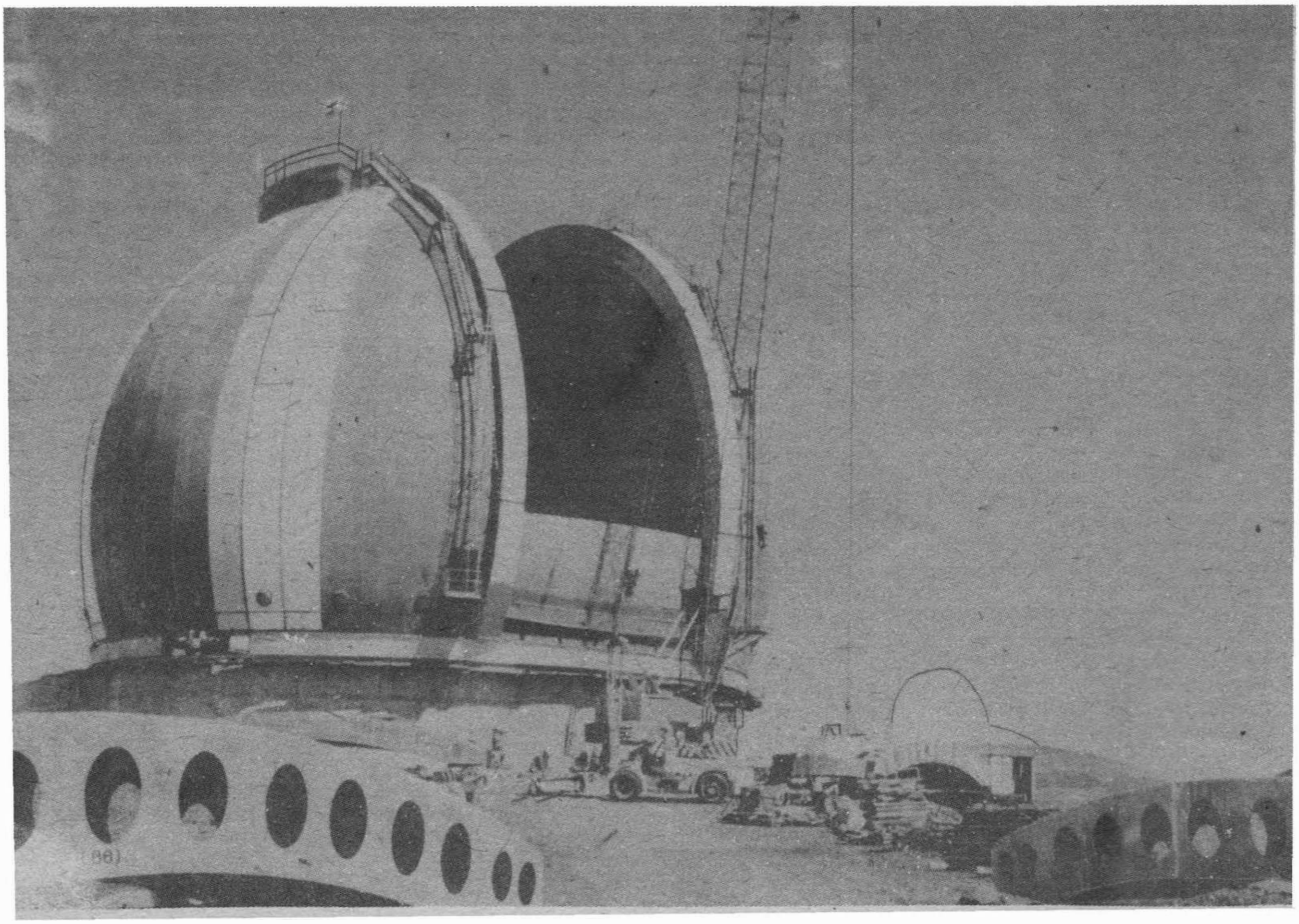
The infrared domain will benefit from the increased resolving power of the instrument as well as its light grasp. Infrared studies will address questions of star formation, the structure of our galaxy (including whether or not it has a black hole in its centre), infrared galaxies and numerous other areas of active research.

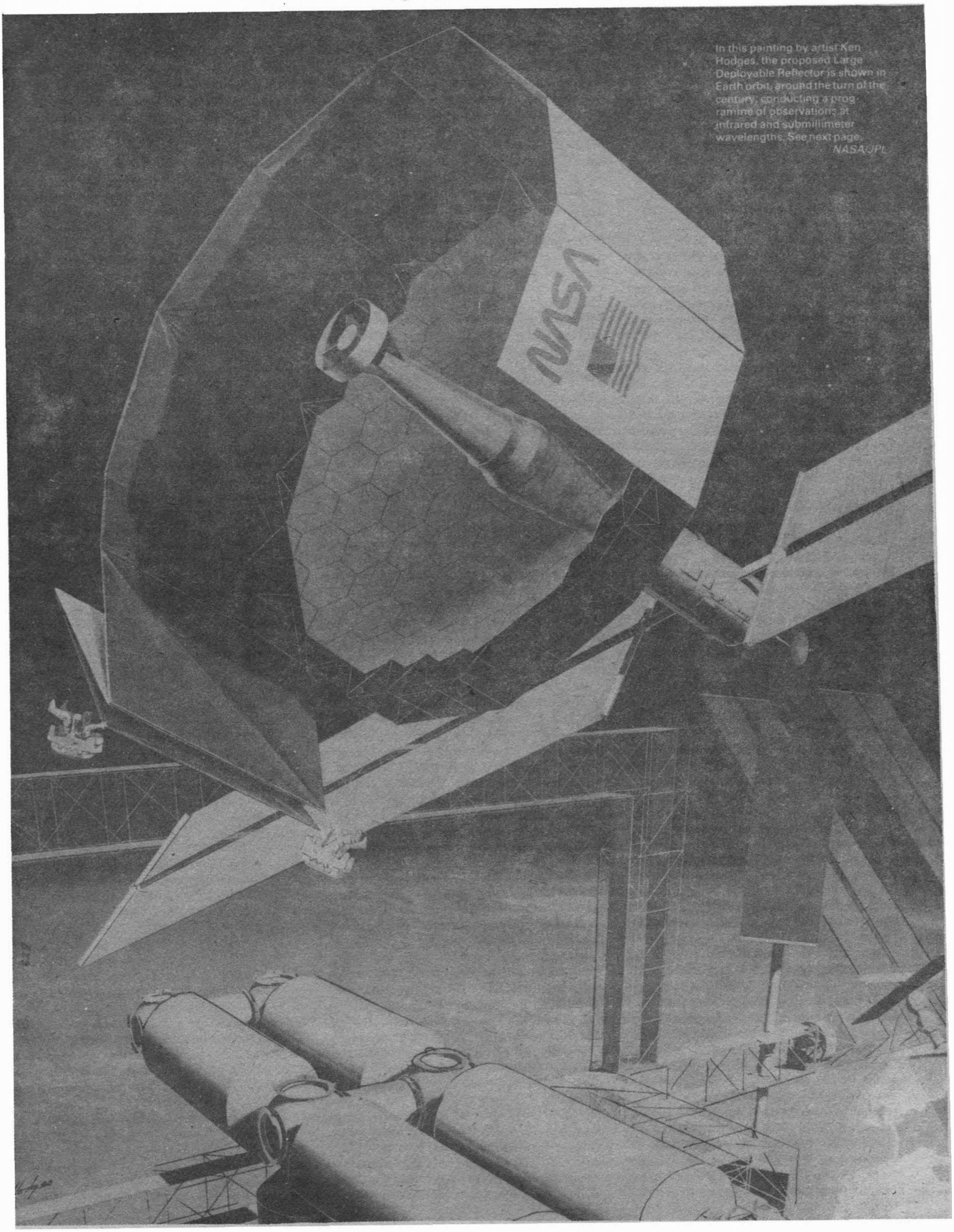
The Sun was down and the stars would be out. Irace and I had come from his upstairs office to the conference room to use the model of the ten-metre telescope. Although it was late and the day before the Thanksgiving holiday, people were still in the building, closing out work, socialising, perhaps a little reluctant to leave for the next four days. It is a good feeling to work on something demonstrably worthwile and add, if only a little, to the delicate fabric of civilisation.



One of the mirror segments in a stress fixture prior to polishing. After polishing, it will be cut into hexagonal shape and placed in the 36-segment mosaic of the primary mirror for the Keck Telescope. *CARA*

The dome for the 10m Keck Telescope on Mauna Kea, Hawaii as it appeared during construction in October 1987. *CARA*





In this painting by artist Ken Hodges, the proposed Large Deployable Reflector is shown in Earth orbit, around the turn of the century, conducting a programme of observations at infrared and submillimeter wavelengths. See next page.
NASA/JPL

Submillimeter Astronomy

For a domain dominated by one parameter, wavelength, the electromagnetic spectrum is an incredibly varied object. It is the primary carrier of information about the physical world, as language is for the cultural world, and ranges from energetic gamma-ray bursts, through familiar visible sights, and out to long radio waves. Isaac Newton introduced analysis of the spectrum in the seventeenth century by splitting visible light with a simple prism. In the nineteenth century, experimenters went beyond visible light – infrared, ultraviolet, radio, x-rays – and James Clerk Maxwell integrated much of the package theoretically with his famous set of equations.

Astronomers have long been following Newton's lead through the science of spectroscopy, deducing much about the chemical and physical constitution of celestial objects from a careful accounting of the amount of light they emit at various wavelengths. It wasn't until after the Second World War that investigators ventured beyond visible light to any significant extent, beginning with radio astronomy at Jodrell Bank and other pioneering institutions. Now, most of the electromagnetic windows have been used for astronomical studies. The submillimeter range is one of the last, relatively unexplored regions.

The importance of submillimeter astronomy comes largely from its contribtion to studies of interstellar gas and dust, in our galaxy and others. This material, at temperatures between 10 degrees and 100 degrees Kelvin, emits most of its energy at wavelengths lying in the submillimeter range: between 0.1 mm and 1 mm.

Relative to other electromagnetic landmarks, the submillimeter range lies adjacent to the long-wavelength end of the infrared and the short end of microwaves. Infrared wavelengths are traditionally measured in microns; a micron is one millionth of a metre. The Infrared Astronomical Satellite (IRAS) surveyed the sky in the region from eight microns to 120 microns (visible light lies between 0.4 microns and 0.7 microns), and in this measure, the submillimeter domain covers 100 microns to 1000 microns. With their shorter wavelengths, infrared objects are warmer than objects characteristic of the submillimeter range – the former class might be described as "room temperature" objects (about 300 degrees Kelvin), such as planets and other structures similarly warmed by a star. Of course, there is no sharp cutoff of emission by an object at the rather arbitrary boundaries of the various electromagnetic regions, and each range can contribute to the understanding of the object under study.

One of the primary goals of submillimeter astronomy is the compilation of a spectral survey of the interstellar medium. Spectral lines arising from rotational and vibrational modes of molecules such as water, carbon monoxide and lithium hydride are particularly important in characterising the various types of molecular clouds in interstellar space, much in the same way that stars have been classified through optical spectroscopy.

One of the primary goals of submillimeter astronomy is the compilation of a spectral survey of the interstellar medium.

Since stars form in molecular clouds by gravitational collapse, it is not surprising that stellar formation is a key concern of submillimeter astronomical studies. The advantage of submillimeter observations is that they provide information about the earliest stages of stellar formation. In the visible range, a new star is revealed only after it has begun thermonuclear energy production and blown away, by radiation pressure or stellar wind, its surrounding cocoon of gas and dust in which it formed. The submillimeter (and infrared) observations allow perception of earlier, cooler phases in the stellar life cycle.

The opacity of the Earth's atmosphere to most submillimeter wavelengths has limited the capability of Earth-based astronomers to take advantage of the information contained in this region of the spectrum. Getting above the bulk of the atmosphere is clearly a favourable approach. The Kuiper Airborne Observatory of NASA features a 0.9 m telescope in a modified C-141 flying at almost 14 kilometres. The 10 m telescope of the Caltech Submillimeter Observatory is situated atop Mauna Kea in Hawaii (along with several other telescopes, including construction for the Keck Telescope – see above).

Infrared astronomy, which is similarly handicapped by atmospheric opacity, made a great stride forward from the observations done in 300 days above the atmosphere with IRAS. A study is currently underway at Caltech/JPL to define a Submillimeter Explorer satellite with the goal of obtaining government approval and placing it in orbit in the middle of the next decade. The Principal Investigator is Professor Thomas G. Phillips of Caltech.

The Submillimeter Explorer would carry a 4 m diameter telescope into polar orbit for two years of observing. The spatial resolution of this instrument would be as sharp as six seconds of arc, allowing one to map the circumstellar shells of Vega, Fomalhaut, Beta Pictoris and others of this class discovered by IRAS (see the April 1984 *"Space at JPL"*). The bulk of the solid particles in their shells are probably about 30 microns to 100 microns in diameter (interstellar dust grains are typically one-tenth of a micron). It is not known whether planet-sized bodies are present in those systems, but circumstellar shells may be important for understanding the formation of planetary systems.

Like the Keck Telescope, the main mirror of the Submillimeter Explorer would be composed of hexagonal segments, fitted together into one structure (but unlike the Keck mirror, the segments would not be actively controlled). In the last five years, technology studies at Dornier Systems in West Germany and within NASA have utilised new materials and processes to produce promising light-weight mirror panels with stable thermal properties.

Although the Submillimeter Explorer would greatly enlarge our understanding of submillimeter astronomy, the light-gathering power and resolution of a truly large instrument above the atmosphere are required. The Large Deployable Reflector (LDR) is a concept for a submillimeter and infrared instrument that could be operating early in the next century. The present JPL concept envisages a 20 m mirror composed of 84 hexagonal panels and capable of supporting observations in the wavelength range from 30 microns to 1000 microns. It would be placed in low-Earth orbit, like the Hubble Space Telescope, and have an operating lifetime of 20 years or more.

Current efforts toward a realisation of LDR are focusing upon the development of mirror panels for the segmented main mirror. The approach combines analytical modelling with the fabrication and testing of panels from promising materials. The goal is to obtain a panel of one to two meters in diameter with a weight of only six to 10 kilograms per square meter and a surface accuracy and stability of about two microns.

Consider the list of NASA's "Great Observatories": Hubble Space Telescope, Gamma Ray Observatory, Advanced X-Ray Facility, and LDR, and contemplate the astronomical riches with which they would close the old century and bring in the new.

A caption to the illustration accompanying "Charting the Future" in last month's "Space at JPL" (p 19) referred to the orbiter as a Shuttle-C, the proposed unmanned cargo vehicle. In fact, the picture represented an impression of a Shuttle II orbiter, a manned version of a possible next-generation shuttle.

UK Space Funding

Letters to *Spaceflight* continue to express readers' criticism of the UK Government's attitude to Space and level of funding. Since November last, *Spaceflight* has urged readers to write to their MPs in order to bring pressure to bear on the country's policy-makers. The value of individual letters to MPs cannot be too strongly emphasised. Just a short letter dealing critically with one or two main points of Government policy or action can be highly effective.

At present, the Government has not finally committed itself on all aspects of space, and time therefore remains for readers to register their opinions and criticisms. In fact, the Government has undertaken to take a fresh look at space funding jointly with industry (*Spaceflight*, January 1988, p.39). Although this is not exactly a U-turn, it does signify that it is prepared to listen and that certain options on future funding are being kept open. Also, it means that it is not too late to be getting a letter off to your MP, but do write as soon as possible.

MPs and Space

Sir, Following recent advice to ***Spaceflight*** readers to speak to their local MPs about government space policy, I had the opportunity to do this recently. I would encourage other readers to do this as I have found this to be useful to myself and informative for the MP who I found to be interested and sympathetic. He confirmed that few people speak to their MPs about Space – so we need to make ourselves more widely heard!

Dr. J.R. MURPHY
Gloucester, UK

UK Space Funding

Sir, I wrote to my MP deploring the Government's attitude to space research and development, and he received the enclosed letter from John Butcher of the Department of Trade and Industry. The latter, of course, misses (or dodges) the central point, that Government should support and fund high-tech research, not leave it to industry.

I.M.HURRELL
Hampshire, UK

Ed. *The letter of Mr. Hurrell to his MP was as follows:*

To: P. McNair-Wilson, MP, House of Commons, London.

As a Fellow of the British Interplanetary Society, I fully support the case put forward in Mr. Hay-Heddle's excellent letter appearing in the Daily Telegraph of October 20, 1987. *We must do our own high-tech research.*

That the BIS's space programme – which if implemented would have put Britain in the forefront of space science – should have been rejected by the Attlee Government was highly regrettable and hard to forgive, but it was at least understandable given the ignorance and indifference at that time concerning space science.

The present Government has no such excuse for rejecting the BNSC's proposed programme. And there is widespread anger over the fact that, after decades of urging deaf governments, we should at last have a national space centre only to have it starved of funds.

I find the attitude of Mrs. Thatcher, who boasts a scientific education, quite inexplicable – "Reducing British industry to third world status" as the Opposition spokesman on space has said.

I hope you will join Sir Geoffrey Pattie and other senior Conservatives of like mind in a forceful effort to persuade her to reconsider her refusal to allow an increase in the space budget to a level commensurate with this country's actual scientific status and potential in forwarding space science. Surely a financial decision-making body whose decisions can be as illogical as giving support to a failed Marxist regiem in Mozambique, while denying it to a vital sector of UK technology, needs to have its functioning and priorities examined with a critical eye.

Yours etc.

Ian M. Hurrell, MVO, FRSA, FBIS

Ed. *The following reply was given by the Parliamentary Under Secretary of State for Industry:*

To: Partick McNair-Wilson, MP, House of Commons, London.

While I can understand Mr. Hurrell's views on the importance of space projects, you will appreciate that we have to balance the longer term benefits of expenditure on space research against alternative uses of funds in support of other areas of British industry.

At the European Space Agency (ESA) Ministerial Council meeting on 9/10 November at the Hague, Kenneth Clarke put forward a seven-point plan calling for a reappraisal of ESA's targets and strategy, with scope for greater involvement of industry and users in the planning and financing of ESA programmes. Several of these points were accepted by member states. Britain did not subscribe to the three new optional programme proposals (Ariane 5, Columbus and Hermes) at the meeting.

In the case of Hermes, the proposed French-led spaceplane project, we were not satisfied that there were adequate industrial, economic, commercial or scientific benefits to justify the substantial expenditure involved. Consequently, we exercised our option not to join that programme. We did not take final decisions on the other new optional programmes. We indicated that we would consider further the proposal for a Polar Platform associated with Columbus in the light of the outcome of the current negotiations with the USA on European collaboration in the international space station. We were also prepared to consider further participation in Ariane 5, if it could be shown to provide a fully commercial launch capability. Our final position on both the Columbus and Ariane 5 projects will be influenced by the extent to which UK industry and users are prepared to be involved in the planning and financing of these programmes.

Arrangements are under way for Government and industry to take a fresh look at UK civil space activities, both nationally and in ESA. We will be looking to the private sector, if it attaches importance to the results of space research, to play an increasingly important role in future programmes.

Yours etc.

JOHN BUTCHER, MP
Department of Trade and Industry

How To Reverse Government Decisions

Sir, It is preaching to the converted to write letters to ***Spaceflight*** deploring the British Government's attitude to Hotol and the downgrading of the BNSC.

To reverse Government decisions, as the Editor noted in a footnote to a correspondent's letter in a previous issue, requires a commitment, and a little work, from each ***Spaceflight*** reader who is also a British citizen and voter.

First, write to both your MP and MEP protesting about the Government's decision and urging him or her to oppose it.

Perhaps those with the time could send similar letters to the Department of Trade and Industry and the head offices of the main political parties, urging a policy review.

Secondly, write to your local newspapers and join in phone-ins on the radio and TV, thereby creating a climate of

opinion in which politicians facing the electorate can dare to speak up for the BNSC.

Emphasise that every pound spent on space is spent on the ground, saving British jobs and promoting British industrial leadership in electronics, avionics, computers and engineering.

Thirdly, pro-space US Congress Representatives and Senators have for years cooperated in a bipartisan Space caucus. In Britian, the initiative could usefully be taken in urging pro-space MPs from both sides of the House, and in both Houses, including the ex-Minister of Trade and Industry, (Sir Geoffrey Pattie), who lobbied hard for the BNSC proposals, to form an All-Party Parliamentary Space Association, similar to those that have long existed in other policy areas.

KEITH GOTTSCHALK
Political Science Department
University of the Western Cape
South Africa

Looking After Ourselves

Sir, It is pointless deploring the Government's refusal to increase spending on space unless we say where financial cut-backs should be made to compensate.

I suggest that aid given to Third World countries be transferred to a British space programme. We have, for example, the incredible situation where Britain provides money for India and yet this 'poor' country has its own costly space industry and now plans its own space shuttle.

Let us not forget that alongside genious, Britain also has stupidity. Unless we act to look after ourselves the 20th century will seem like a glorious era in space compared to our obliteration in the 21st.

C. SIMPSON
Essex, UK

Ed. *Mr. C. Simpson has no relationship to* **Spaceflight's** *assistant editor, Mr. C.A. Simpson.*

Energia Payload Engine

Sir, May I comment on Mr. Bond's interesting observations (***Spaceflight***, January 1988, p.15) regarding the Energia model exhibited at Brighton, in the light of my own letter published in ***Spaceflight***, November 1987.

The cross-sectional configuration for Energia published with that letter indicated that a dynamic imbalance would exist at lift-off unless a thrust contribution was forthcoming from the payload. In other words it is like the US Shuttle, where the weight and drag of the side-mounted orbiter are offset by the thrust of the orbiter's engines.

With Energia, the magnitude of the effect is much smaller, so far as can be calculated from the reported engine thrusts and estimatable weights of the core and sideboosters. At lift-off a balancing thrust of some tens of tons may be needed at the payload. Providing this may be the function of the two small boosters at the base of the payload, evident in the model.

While balance is obtainable this way at lift-off, continuous control of the various thrust sources is necessary as the rocket climbs, in view of the changing fuel masses, increasing acceleration and aerodynamic drag. The question arises, did the Energia payload make an increasing thrust contribution by means, for example, of an engine of ramjet or Hotol type?

It seems probable that the Energia payload was a test of systems for the Soviet shuttle. Of primary importance are the engine systems it is bound to carry, despite the absence of large rocket engines as on the US shuttle. There is certainly an in-space manoeuvring system, for final orbit injection, attitude control and de-orbiting, but there may also be engines able to exploit the atmosphere, particularly at upper levels. This would usefully extend the vehicle's capabilities.

One might expect the purpose of the first Energia launch to be to take the Soviet shuttle's engines, of whatever kind, through an operational test flight. It was a fault not in the engines but in the orientation system which caused the payload to be de-orbited instead of injected into a higher orbit. This was officially stated (*Izvestia*, May 23).

The payload did not, according to the official statement, plunge uncontrollably into the Pacific, but came down to the water surface in the same manner as the core stage. But while the core stage came down at the predetermined point, and was conjecturally recovered, the payload's descent into the Pacific was unscheduled. Conjecturally again, the intention was to de-orbit it, after mission completion, over the Soviet Union. One is left asking whether it was possible to recover it from the Pacific, and what condition it was in after a reportedly fiery re-entry.

The origins of the Energia model at Brighton are enigmatic. It looks as if it might have been made by craftsmen who were given enough information, probably pictures, to produce a plausible model without being technically exact. For example, the aspect ratios of the model, that is to say the ratios of height to width for the various components, agree with those which can be directly measured off the published pictures of Energia. But these pictures show considerable perspective distortion and it is clear that aspect ratios so obtained need recalculation to allow for this. As a result, Energia is really more squat than the model indicates.

What we would most like to know about Energia is how big it is. The true dimensions and aspect ratios are basic to this question, for when they are known the similarity of Energia's tankage construction to US construction for identical propellants gives confidence to volume and weight calculations. Taking account of perspective factors, these increasingly point to a launch weight of up to 3000 tons for the four-sidebooster configuration. With 4000 tons of thrust, Energia is seemingly a rather larger rocket than Saturn V, and might put 150 to 200 tons into low-Earth orbit. The four-sidebooster configuration is probably destined to remain standard for a long time to come.

TONY DEVEREUX
Essex, England

Listening To The Cosmonauts

Sir, I find ***Spaceflight*** magazine very interesting especially the issue of October 1987 which contained a very interesting article "Listening to the Cosmonauts" by J. Branegan.

I would like to make listening to cosmonauts my hobby and I would like to buy satellite tracking with graphics software for my Sinclair Zx Spectrum 128K or 48K. Could you please say who could help with this.

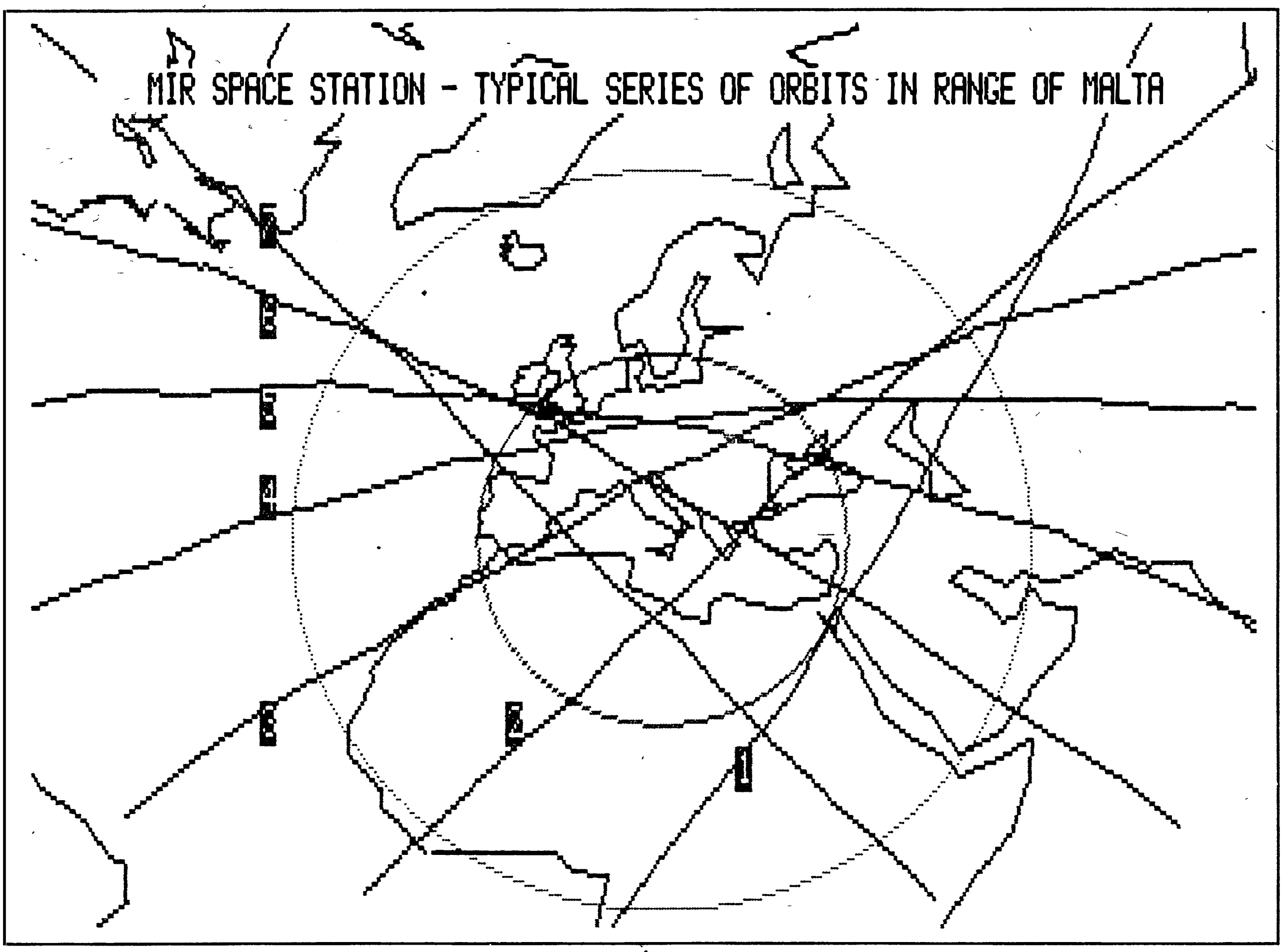
JOSPEH CHIRCOP
Qrendi, Malta

Commander Branegan has kindly provided the following information:

All the software needed can be obtained from: Sinclair Amateur Radio User Groups (SARUG), 3 Red House Lane, Leiston, Suffolk, England.

They supply software for all types of Spectrum computer, and they also have programs for the Sinclair QL and some Amstrad computers. All satellites of interest are covered by this software, including Mir, Salyut, Space Shuttle, Radio Amateur Communication and Experimental satellites, and Weather satellites. Orbit types covered include Low-Earth, near circular, Molnya Elliptical orbits and Geostationary orbits.

All these programs require that you provide them with up-to-date positional information for the satellite of your choice, either as Keplerian elements, or in some programs only, as Equatorial Crossing times and Crossing Longitudes. The easiest regular source of this data is *Practical Wireless*



Stations in the Mediterranean can hear up to seven successive Mir orbits each day. Although orbits passing over the Western Mediterranean are out of range of Soviet Ground Control, there has been a Soviet station or Comship near Madiera since November '87, and Mir has been heard talking to it regularly as it moves south towards the Equator, preparing to look at Super Nova 1987 with its Kvant X-ray telescopes.

Magazine monthly. Most of the programs cover tracking data with graphic maps, and some cover special features such as the question of when you can see Mir/Shuttle visually against the predawn, or post sunset sky.

Care is needed with Mir as, even with up-to-date Keplerian elements, these can be out of timing by several minutes when one of the regular engine firings changes the orbit as it did on November 16, 1987.

All programs supplied by SARUG work anywhere in the world, but users who speak Japanese, Russian or Spanish will find that these SARUG/GM41HJ programs, as they are called, are available in these languages and scripts from licensed distributors in the particular country's Amateur Radio organisations.

Mediterranean Mir watchers and listeners have a rather improved view of Mir compared with the UK picture reported in ***Spaceflight***. The accompanying diagram shows the Mir picture for Mediterranean users.

Model Making

Sir, I subscribe to your magazine and I am a rocket modelist. I have been going in for this hobby for four years and have had some success. I was placed second in the championship of the USSR in 1985 and again in 1987. I am currently planning to make a model of the carrier-rocket Saturn 1B with the Apollo spacecraft.

GAPON YURII
nr. Kharkov, USSR

Informative Exhibition

Sir, The Sixth Form Physics students of St. Swithun's School, Winchester attended the 'Education Day' of the SPACE '87 Exhibition in Brighton. We all enjoyed the day very much as well as finding it most informative.

GRACE WEBBER
Winchester, England

Common Sense Spaceplane

Sir, Your article about the Teledyne spaceplane (***Spaceflight,*** December 1987, p. 413) told of a welcome return to common sense. If we are ever to get anywhere – literally or figuratively – a reliable, low-cost launcher is absolutely imperative.

Mention of possibly boosting the 747's high altitude capability by converting it to eight military engines immediately evoked a mental picture of the B-52, which just might be a more suitable "first stage". It already has the eight military engines, and its high altitude performance is substantially better than that of a 747.

Best of all, the USAF has hundreds of them in cocoons at Davis-Monthan AFB, and could probably be persuaded to lend a few free of charge for so worthy a cause!

Perhaps the concept could be scaled up by coupling two B-52s (or two 747s) for the first stage, rather like the Double Mustang of the Korean War.

W.J. TOMLINSON
Woking, England

CORRESPONDENCE

Energia Nozzle Design

Sir, A.T. Lawton's article on "Energia – Soviet Super Rocket" in ***Spaceflight***, August 1987, conjectures that Energia uses plug nozzle or "aerospike" engines. This design is explained well in Bono & Gatland's *Frontiers of Space* and, as I understand it, an aerospike engine does not have a spherical combustion chamber like a conventional bell nozzle engine. Sadly, the photograph of a Soviet model (***Spaceflight***, December 1987, p.405) depicts Energia as having spherical combustion chambers, at least on the central core. So what is the 'advanced motor design' which the Soviets are stated as claiming?

MIKE SALMON
Norwich, England

Mistaken Identity

Sir, A letter from Philipp van Stratum (***Spaceflight***, November 1987, p.368) states that he believes the mockup of Mir displayed at the 1987 Paris Air Show was simply a rebuilt Salyut 7 model from the 1985 Paris show. Perhaps he meant to say the 1983 show, because I attended both in 1985 and 1987 and if Salyut 7 was there two years ago then I must have been at the wrong air show.

I also do not agree with him that the Mir was built using the old Salyut 7 mockup. I have seen a mockup of Salyut 7 at Expo 86 in Vancouver, Canada, and in my opinion the Salyut model was crudely built in comparison to the Mir shown in Paris. In any event the Salyut mockups seem to have been entered from below, up through the "floor", while I entered the Mir through the side wall to view the interior.

J.W. POWELL
Alberta, Canada

Soviets Reveal More About Past Crews

Sir, Much has been made of the Soviet policy of Glasnost, but it is true to say that there is a new openness in the Soviet manned space programme, which has been reflected by open discussion of Energia, the shuttle programme and more recently, Vladimir Shatalov's frank criticism of the "lack of purposefulness and consistency" and "lack of a good programme with a precise formulation of goals".

Moreover, this openness is not restricted to current developments and consequently we are now, at long last, beginning to learn more about events of 25 years ago.

In my recently published book "The Soviet Cosmonaut Team" [1], I examined many aspects of the Soviet Union's manned space programme in great detail, and in particular, I tried to shed new light on such things as the selection groups and crewing policies.

Two of the biggest mysteries I discussed were the identities of the other women chosen with Valentina Tereshkova in 1962, and the crewing of Salyut 1.

The first has now been resolved, with the release of the names of Tereshkova's team [2]. Five women were selected, not four as always believed, and they were:

Valentina Vladimirovna Tereshkova
Irina Bayonovna Solovyova
Valentina Leonidovna Panomareva
Tatiana Dmitryevna Kuznetsova
Zhanna Dmitryevna Yorkina

Solovyova was the back-up and Panomareva the support. Details are still emerging but it seems that the women were not disbanded until 1969, and at one time were training for a Voskhod mission during which one of them would perform an EVA. In my book I presented the evidence for a Voskhod 3 and possible joint Voskhod 4/5 mission. This newly revealed flight would, I think, have preceded the planned Voskhod 3 mission. All the women except Tereshkova are still working in training jobs with the cosmonauts.

The second mystery concerned the third crew member who had trained for Salyut 1 with Leonov and Kubasov. He was known to be a military engineer, possibly selected in 1963. We now know he was Pyotr Ivanovich Kolodin and he was indeed selected in 1963. It has also been confirmed that the three men were prime for Soyuz 11 and were only replaced by the back-up crew two days before launch, following the discovery of a spot on Kubasov's lung [3].

And finally, readers may be fascinated to learn that in July 1965, two Soviet journalists were selected to train for a space flight. The two men were Yaroslav Golovanov and Yuri Letunov [4]. Both left the programme shortly after Korolyov's death, but have since written extensively on the manned space programme. In particular, Golovanov wrote the series of articles published in *Izvestia* in April 1986 giving the names and backgrounds of the unknown members of the Gagarin selection.

There is a great deal more for us to learn, but all the evidence so far suggests that the Soviets may be very forthcoming over the next few years, particularly about the very earliest years of their space programme.

GORDON R. HOOPER
Lowestoft, Suffolk

References

1. "The Soviet Cosmonaut Team: A Comprehensive Guide to the Men and Women of the Soviet Manned Space Programme." GRH Publications.
2. "Rabonitsa" (Female Worker) No 10, 1987, pp 2-5
3. "Gody ispytaniy" (Years of Trials) by Nikolai Kuznetsov, 1987, pp 302-308
4. "Literaturnaya Gazeta", April 1986, article by Golovanov

Soviet Back-up Crews

Sir, I would like to reflect on Mr. Bart Hendrickx's suggestion (***Spaceflight***, December 1987, p.431) that Soviet cosmonaut Alexander Viktorenko does not fit the pattern of "back-up crews" (as stated in the Izvestiya) but has more likely been a member of a support crew assignment.

I think Viktorenko does fit. Could it be possible that Viktorenko was initially selected as a member of the 1970 Class and that he returned (after the electrocution-incident) in 1978? His age (year of birth 1947) suggests that he was the youngest, or one of the youngest, of the 1970 Class, and this certainly fits the "young and inexperienced" label for this particular group of trainees.

I suggest that Viktorenko must have been the original Soyuz 13 back-up commander, with Sevastyanov being the back-up flight engineer. In fact this is the only slot appropriate. The back-ups to Soyuz 13 have never been positively identified, though Sevastyanov was suspected of being on that crew. Once Bykovski was suggested, too. But does he fit?

Another suggestion: A certain Ilyin was the original Voskhod 2 doctor. Yegorov was back-up first. For some reason Kamanin selected Yegorov at a later stage for the final flight-crew. Ilyin would have been a cosmonaut from 1964 to 1967. Could it be that Professor Yevgeny Ilyin, head of the scientific research programme on Soviet biosputniks is the same Ilyin? He is also the man heading the work on Medilab Mir 2 module.

Finally I can confirm that two of the back-ups for the Tereskova mission (Vostok 6) have been identified as Irina Bayanovna Solovyova and Valentina Leonidovna Ponomareva. Also, the name of Pyotr Ivanovich Kolodin has been disclosed as the third man of the Leonov/Kubasov crew on Salyut 1.

ANNE van den BERG
Sliedrecht, The Netherlands

CORRESPONDENCE

Energia Engines

Sir, Having read ***Spaceflight*** since first seeing your '30th Anniversary of Space Exploration' special edition, I have been particularly interested by the on-going correspondence you have published concerning the Soviet space programme. If I may I would like to add some comments of my own on this subject.

Firstly, I agree with Mr. Beslity (***Spaceflight***, November 1987, p.371) that the new SL-16 launcher probably used both types of engine employed on Energia. But I believe that, given its probable diameter of 4.15 metres; first stage length of 30 metres at 300 tonnes weight (shortened from its Energia strap-on-booster version); and second stage length of 20 metres at 150 tonnes weight, its maximum payload to low-Earth orbit (LEO) will be 20 tonnes, and this only if fitted with smaller strap on boosters on its first stage. The launcher thus being flexible enough to launch payloads from 15 tonnes up to that of the present Proton launcher, which it will eventually completely replace.

Although a serious development programme for a 15 to 20 tonne shuttle may once have existed, I disagree with Mr. Lawton that it will soon emerge as an operational vehicle (***Spaceflight***, November 1987, p.370). Instead, work such as the Cosmos 1445 test has probably provided data for the development of a larger shuttle, which has reportedly made four test landings to date. This shuttle itself probably weighs at most 60 tonnes unloaded, given both the performance of the aircraft it has flown piggy-back on, and the Soviet desire to allow room for error in payload weight for manned vehicles on Energia, only the second launcher the USSR will have used for manned launches in history,

Regarding the Energia launcher itself, I see no reason to argue it will eventually be developed into a very complex eight strap-on-booster, three stage vehicle capable of placing 185 tonnes into LEO. Its present 100 tonne capability seems fully adequate for any conceivable paylaod. From the large shuttle at around 80 tonnes fully loaded later this decade, to the 'Mir 2' LEO space station core module at 100 tonnes, and 25 to 30 tonne payloads for geostationary, lunar and planetary orbits (with a 70 tonne cryogenic side mounted third stage) in the 1990's.

PAUL J. MANT
Eastbourne, Sussex

Mir in English

Sir, Simon Barnsley (***Spaceflight***, September 1987, p.345) raises the matter of Mir in English. There are in fact three translations – (a) peace, (b) world, or even universe in some contexts, and (c) a village community. You can take your pick in terms of the language but surely in conversation with westerners some of the Soviet officials must have said which meaning is intended?

H.J.P. ARNOLD
Hampshire, UK

Newton Commemorated

Sir, A large exposition was held by the University of Leuven during November 1987, entitled "From apple to atom: physics after Newton" to commemorate the 300th anniversary of Newton's Principia. It was a tremendous success attracting 45,000 visitors. Being a graduate student of physics, I had the duty (and also the honour) of being a guide at the exposition, and I did not miss the opportunity to make some mention of the Society whenever possible. I always wore my Society tie and lapel badge.

The exposition will be held a second time in February 1988 in the city of Kortrijk and I can strongly recommend it.

KRISTIAAN TEMST
Meerbeek, Belgium

Launch Puzzle Answer

Sir, In your reply to a recent letter from Mr. Gordon Davie (***Spaceflight***, January 1988, P.27), I was surprised to read that your contact at the Johnson Space Flight Center had no knowledge of the "1 Bravo", "1 Charlie" calls made by the CAPCOM during Appllo/Saturn launches. These did indeed refer to various escape modes and were documented as nominal launch phase voice callouts to be made during the boost-to-orbit phase.

Modes 1a, 1b and 1c utilised the Launch Escape Motor on the Launch Escape Tower (LET) to pull the Command Module (CM) clear of the Launch Vehicle (LV). Modes 2, 3 and 4 used the engines of the Service Module (SM). In the following (highly simplified) summary, the timings are based on the SA508 (Apollo 13) mission; actual timings varied from launch to launch.

Mode 1a – Low altitude abort (up to 42 seconds after launch) The Pitch Control PC motor on the LET used to propel the CM far enough down range to ensure a landing in water.
Mode 1b – Medium altitude abort (42 seconds until 100,000 feet altitude). Similar to 1a, but the PC motor not used. The CM/LET was aerodynamically tumbled into the Blunt-End-First attitude by means of the Canard Subsystem on the LET.
Mode 1c – High altitude abort (over 100,000 feet until LET jettison) During this period the LV was above the atmosphere and the Canard Subsystem could not be used. The CM was manually manoeuvred for re-entry.

Mode 2 – (from LET jettison at 3 min 20 sec until 10 min 15 sec). Either S M Reaction Control System engines or main SM Propulsion System (SPS) used to separate the CSM from the LV before manoeuvring the CM for re-entry. (The decision as to whether to use RCS or SPS depended on the stability of the LV and the degree of danger at abort).

Mode 3 – (10 min 15 sec until orbital insertion). SPS used in a retrograde manoeuvre to slow the CM for splashdown in the Atlantic.

Mode 4 – (9 min 7 sec until orbital insertion). The SPS could be used to boost the CSM into a contingency orbit at any time after the LV got within 3000 feet per second of orbital velocity. The CM could then re-enter at leisure.

I hope these brief notes are of interest to Mr. Davie and any other ***Spaceflight*** readers.

NEIL MORRISON
London, England

Sir, I refer to the letter from Gordon Davie in the January 1988 issue of ***Spaceflight*** regarding the calls "One-Bravo, One-Charlie" made during the launch phase of the Apollo missions.

He is quite correct in assuming that they were to do with launch escape methods, and I must confess some surprise that your correspondent in Huntsville was unable to be more helpful to him.

There were, in fact, four Modes of escape, and far from being an ".... informal communications procedure" as you say, were most necessary to inform the astronauts which of these four routes to take to safety.

I trust that this will clear the question regarding these strange calls.

E.T. PUGH
Essex, England

Ed. *Mr. Pugh's letter also contained similar details of the various launch escape modes to those given in the previous letter. Our thanks to both correspondents for clarifying the question raised by Mr. Davie.*

President Calls for Greater Government Commitment to Space

The Government's recent freeze on UK space funding and the continuing uncertainty about future funding is harming Britain's position in Europe and internationally, according to BIS President, Mr. Rex Turner.

"A new Government initiative is needed to restore confidence and enable Britain to achieve its full potential in the high-technology future of space," said Mr. Turner, who until his retirement two years ago was Technical Secretary of Eurospace, the organisation representing European space industry.

He pointed out that a lesson to be learned from recent events was that the BNSC must now be given every opportunity of fulfilling its role properly without major political upsets.

At present the Government is pursuing the idea that industry itself can significantly contribute to the funding of space developments, but he felt that this was only a partial answer to present needs.

"The private sector already supports a number of commercially-attractive projects but it is only the Government that is in a position to fund the longer-term developments involving initially unproven techniques," said Mr. Turner.

He considered that other countries, notably France, had long ago come to understand the respective roles of industry and government in promoting space, whereas in Britain successive Governments had failed to grasp the basic fundamentals of the space business and to act realistically.

While the present situation is not at all to our liking, his message to the Society is that "it makes our work and influence all the more essential".

The Society's main event in 1987, the SPACE '87 Exhibition, coincided with the Government's announcement of a freeze on space funding and served as a focal point for media attention as reporters and camera crews descended on Brighton looking for interviews. The question of 'Britain's role in Space' came to public attention as never before, epitomised by Hotol and the threat to its continued development.

Mr. Rex Turner (right), BIS President, and Mr. John Butcher MP, the Parliamentary Under Secretary of State for Industry, at the reception hosted jointly by the Society and the Department of Trade and Industry for delegates to the 38th IAF Congress in Brighton on October 12, 1987.

Public interest in space has been at a high level since and it is vital that it should continue and that the message of public concern gets through to the policy-makers in Government.

In mid-December, this concern was voiced by HRH the Prince of Wales when he criticised the Government's failure to back Hotol, fearing that it might become one more British invention to be lost to foreign interests.

Asked what part individual members should play in the present crisis, Mr. Turner emphasised the importance of keeping the question of UK space funding alive in the public and political debate. "Ironically the sums of money called for are relatively small compared with other demands on the Exchequer, yet the potential benefits to the country cannot be overstated," he said.

"Many members have written to their MPs to express their concerns and the value of this will increase as more and more people get round to sending off letters. I earnestly recommend members to make their views known on every possible occasion, particularly to their MPs, and so back up the work that the Society is already doing."

Support for the Society

The Society is gratified by expressions of support that it is now receiving in recognition of its work at a time when space is facing an uncertain future in Britain.

At such a time, the Society is all too conscious of the fact that its resources are not unlimited and need to be increased in all possible ways by, for exmple, the addition of new members to its ranks and by donations and support from existing members.

Squ.Ldr R.A. Cooper, FBIS, MAIAA, MIEEE writes to us saying:

The future indeed looks bleak for British participation in Space, but keep up the excellent job you are doing of making those concerned aware of the implications of this sorry state of affairs. We must not turn our backs on this new frontier, and you have my full support whenever or wherever you need it.

Please find enclosed my cheque for a contribution to the BIS Building Appeal. I will be sending additional small, but hopefully useful, amounts during the coming months and hope you will keep us up-to-date on the progress of the appeal.

The lastest news of the Appeal is that the total has increased sharply during December and January. One-tenth of the £80,000 target figure has been reached and the total is still increasing, but there is a long way to go. Every contribution, of whatever amount, brings our plans that bit nearer to being fulfilled.

IAF Congress Arrangements

The Society's efforts in hosting the 38th IAF Congress last October have been the subject of continuing expressions of appreciation received at our Offices from participants:

The very best wishes for 1988! Many thanks again for all you have done for the 'turbulent' IAF Congress in Brighton!

JOHANNES ORTNER
President, IAF

You have our best wishes and sincere admiration for a job well done at the IAF Congress, Brighton in spite of immeasurable odds! I did not realize until recently that

the closing banquet was so near to going ahead as scheduled.

PETER BAINUM
American Astronautical Society

The Society was involved in discussions at Brighton with delegates from India and China, in whose countries the 1988 and 1989 Congresses will be held respectively, and the Society was pleased to have this opportunity to brief those concerned with arranging these forthcoming Congresses on its own experiences in promoting the 1987 Congress.

This year's Congress will be held in Bangalore, India from October 8 to 15. Those wishing to present papers should note that the Abstract deadline is March 1, 1988. Procedural details for the submission of Abstracts may be obtained from: The International Astronautical Federation, 3-5 Rue Mario-Nikis, 75015 Paris, France.

Society Publications

Project Daedalus Report: Following the announcement in the last issue of ***Spaceflight*** that only 120 copies remained in stock, the demand has been heavy and only a few copies now remain.

High Road to the Moon: Stocks of this book are fast diminishing and are expected to run out by the end of June. Copies are available only from the Society and may be obtained at a price of £6.00 (US$10.00) each, inclusive of post and packing.

Congress Newspaper: 'Congress News' was published by the Society as a souvenir colour newspaper recording the events of the week of the 38th IAF Congress and accompanying SPACE '87 Exhibition, last October. Copies are available on request enclosing a self-addressed label and postage of 20p.

APPEAL – Latest Report

In May 1987, the Society launched its £80,000 Building Appeal Fund for a much needed extension to its Headquarters. The new building will be on two floors connecting with the Conference Room on the ground floor and the Library on the floor above.

The Society records its thanks to the many contributors whose donations have now taken the fund total above £8,000. The total is being added to daily as members send to the Society to renew their memberships for 1988 and at the same time include an extra amount for the Building Fund.

Total: **£8,000**

Your generous support will be gratefully received and acknowledged. Send to:
The Executive Secretary, The British Interplanetary Society
27/29 South Lambeth Road, London SW8 1SZ, England.

Library Books for Sale

Books surplus to the needs of the Society's library are being offered for sale at much reduced prices. Members who have previously obtained a copy of the list of such books may like to know that a further list of surplus items is now available on request. Please send a stamped addressed foolscap envelope.

As only one copy of each book is held, would-be purchasers are urged to reserve copies by telephone beforehand to save unnecessaary correspondence.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

3 February 1988, 7-9 pm — **Lecture**

ENCOUNTER WITH HALLEY'S COMET

Prof. J A M McDonnell

Members only. Please apply for ticket, enclosing SAE, in good time.

5 March 1988, 10.30 am — **Visit**

UNIVERSITY OF SURREY

A tour of the UoSAT Spacecraft Engineering Unit for BIS members. Further details from: Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose SAE. Numbers will be restricted so please apply in good time.

9 March, 1988, 7-9 pm — **Lecture**

HOTOL—A SPACEPLANE FOR EUROPE

G P. Wilson

Members only. Please apply for ticket, enclosing SAE, in good time.

23 March 1988, 10-4.30 — **Symposium**

HISTORY OF BLACK KNIGHT

An all-day Symposium. Refreshments will be provided and as numbers are limited early registration is advised.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

4 June 1988, 10-4.30 — **Symposium**

SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

EUROPEAN RENDEZVOUS

Britain's Space Future

by Roy Gibson

The season of goodwill to all men should have been a propitious time to take stock of Britain's future in space, but I confess that even the athletic turkey and Christmas pudding was easier for me to digest than the off-hand way in which the UK government once again decided to opt out of the next generation of space.

We are too close to the events for a thorough analysis of what went wrong, but it is already clear that the seeds of the disaster were sown in the second half of 1986 and the first half of 1987, during which period the draft National Space Plan waited in vain for serious government consideration.

Roy Gibson examines a model of the French-built Spot remote sensing spacecraft. Mr. Gibson, a prominent figure in European space affairs over many years was the first Director General of ESA in 1975 and become head of the British National Space Centre in November 1985 until his resignation last September. He is currently Special Adviser to Inmarsat's Director General, Olof Lundberg.

Roy Gibson asks: *What Went Wrong?*

During this same time the European Space Agency (ESA), following the instructions given by Ministers in Rome in January 1985, was preparing the new long-term plan destined to cover up to the year 2000, and there were frequent meetings of a working group of national delegates charged with producing the necessary documents for the second Ministerial Council then scheduled for June 1987.

Lacking a decision on the National Space Plan, the UK delegates could do no more than examine the proposals starting from first principles. We therefore concentrated on flushing out the total probable cost of the proposed programme and we insisted time and again that the estimates being presented by the executive were in many cases frail, and that the total bill would not only be considerably larger than agreed in principle by Ministers in Rome, but would be too big for the European space family to sensibly undertake. We also urged both the Executive and our partners not to repeat the mistake NASA made with the shuttle programme, where cost over-runs had to be paid for by cutbacks in user programmes.

In fact, many delegates approved the line we were taking, and it is fair to say that we had some success in bringing more honesty into the programme. Of course, our fatal weakness during those meetings (which were in fact preliminary negotiations) was our inability to say what we were "for" as opposed to what we could not accept or criticised as being incomplete. We were authorised at that time to keep open all programme options and to assure our partners that we still held to what was known as "the spirit of Rome", but we could make no promises.

Many other delegations also lacked clear governmental instructions, but the three other large players at least had general guidance and, whilst not knowing the extent of the budget to be devoted to space, they all had the assurance that space activities had basic governmental support. These three member states, plus the UK, usually contribute well over 80 per cent of the ESA budget and so the uncertainties of the smaller contributions were not decisive. There is no doubt that many of the smaller countries were looking to the UK for a lead.

The UK delegates had less success in persuading others that the new programme contained major inconsistencies, and that more effort and time were needed to consider the interactions between the various elements of the programme. Perhaps we argued the case badly, but we were not helped by our inability to put any firm commitment on the negotiating table. It was, on the contrary, becoming increasingly probable – one deduced from the will o' the whisp-like discussions back home – that the Rome agreements in principle no longer represented a firm basis on which we could negotiate in ESA. This evident vacillation was apparent both to delegations and the ESA executive.

Space is not something that can be written out of the script in the way a troublesome actor is removed from a soap opera.

The General Election in June 1987 and the change of Ministers administered the coup de grace. That it could have been delivered with the skill of a matador rather than the methods of the abattoir, did not go unnoticed abroad. The majority of 12 member states rallying to the Director General's proposals – an unprecedented majority – was more a consequence of the UK's spoiling attitude than a tribute to the Director General's eloquence. And all because, it seems to me, we were incapable between January 1985 and November 1987 of directing sufficient high-level attention in a timely way to give us the space policy we needed – and still do need.

A contributory factor to our failure was no doubt the rather make-shift way in which the British National Space Centre (BNSC) had been established. Too much had been left to gentlemanly agreements and too many departmental sticking points had been temporarily shelved. As soon as the going started to get rough, the strain began to tell.

No doubt in due time the whole saga will make a fine doctoral thesis for some earnest graduate from the USA and – such is our reputation at least – we in Britain will be among the first to smile at the quaintness of it all.

In the meantime, however, I still find it difficult to acquire either the indifference or the complacency to consider the chapter closed. If this had been an attempt to obtain funds for a bridge, a trunk road, a reservoir or even a new fighter plane or tank, the damage would have been less – perhaps another attempt could be made in a few years' time. I am not sure that the same applies to the fast developing world of space. Obviously, if space were to find itself in the top-ten of governmental policy buzz-words long enough for additional funding to be made available, a new British space programme could again be mounted. But it would not be easy. Not only will industrial work on the new ESA infrastructure programmes be fully booked and jealously guarded against predators, but Britian's capacity to perform at this hi-tech frontier will undoubtably have been seriously eroded.

It must therefore be the aim over this next year or so to try to conserve an active nucleus of space competence. Primary responsibility for this must rest with BNSC, and it is to be hoped that the organisation will not only be retained, but organisationally strengthened so that it can undertake the national co-ordination which becomes more important than ever in the lean years to come.

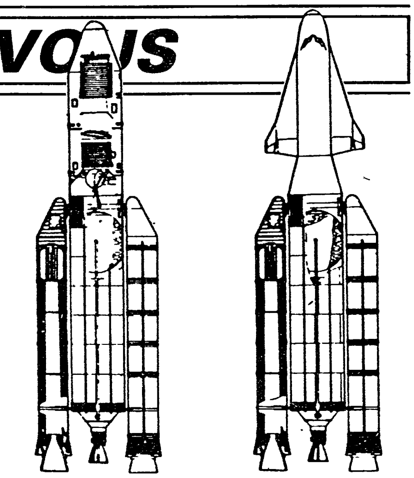
Much has been made of the need for industry to invest more in space, but I am personally sceptical that the private sector will collectively produce significant sums unless there is additional investment from government. Individual areas of commercial opportunity will, of course, present themselves and our industry is still able to pursue them on the strength of its existing competence. But collective investment in space by the private sector needs the partnership of government, and must hold promise of widespread benefit to industrial companies. Such an objective is not attractive to the larger aerospace firms unless they realise it is the price they have to pay for even a modest but assumed increase in government funding.

It will be interesting to see how the situation develops in these coming months. Public and parliamentary interest in space is still strong and it is probably the right time in the cycle for the whole, rather annoying, problem of space in the UK to be made the subject of a thorough-going report by someone unencumbered by any experience in the field. There can surely be no shortage of candidates.

And what can we do to help? We must keep the light burning. Space is not something which can be written out of the script in the way a troublesome actor is removed from a soap opera. The developments will continue and the British Interplanetary Society has an enormous responsibility to try to keep the British space community informed and to help off-set the tremendous disadvantage we shall suffer from isolation from major European and other space programmes.

Above all we must continue to help future generations not only gain our enthusiasm for space, but also to understand how it can best be used to solve the many problems which beset us and, even moreso, those in the developing countries. In many ways it will feel like playing football without a ball, but then, if we continue to train and practice, maybe one day the government will give us our ball back.

EUROPEAN RENDEZVOUS



ARIANE 5 Europe Backs Space into 21st Century

The $3.5 billion Ariane 5 project for a heavy-lift launch vehicle received the go-ahead for its development phase at last November's ESA minister's meeting (*Spaceflight* December 1987, p.408). The final demonstration flight of Ariane 5 is scheduled for 1995 and the first commercial flight for 1996, with the manned Hermes-Ariane 5 version to follow two years later. Operational Ariane 5 missions are expected to be at a rate of eight per year from 1998. In this report, *Spaceflight* highlights the ideas and plans that lie behind Europe's intention to enter the 21st century as a leading space power.

Matching Up To The Competition

From 1995 onwards most satellites to be put in geostationary orbit will be of increased weight (2000-2800 kg) and unless Ariane 4 is replaced by a higher performance vehicle Europe will no longer be competitive in this lucrative international market.

There are significant economic advantages of launching two satellites from the one vehicle, a so-called 'dual' launch, whereby better use can be made of vehicle payload capacity. Ariane 3, which is able to lift 2560 kg into GTO (Geostationary Transfer Orbit), carried out its first dual launch in August 1984. The Ariane 4 programme, currently due to commence with its first launch next month (March), will continue the policy of dual launches, achieving the capability of lifting 4200 kg into GTO with Ariane 44L, the highest performance version of the Ariane 4 series.

However, higher payload weights to be expected from the mid 1990s mean dual launches on Ariane 4 will no longer be routinely possible and Europe, at present favourably placed in the international launch market with its Ariane 3 and 4 vehicles, could find its position undermined by developments elsewhere.

The US and USSR are both actively up-rating vehicle performances. Following the Challenger accident an improved Titan launcher is being developed which will accommodate satellite diameters to 4.55 m (to match the shuttle) compared with Ariane 4's 3.65 m. China and Japan are also both actively advancing their launcher technologies and performance.

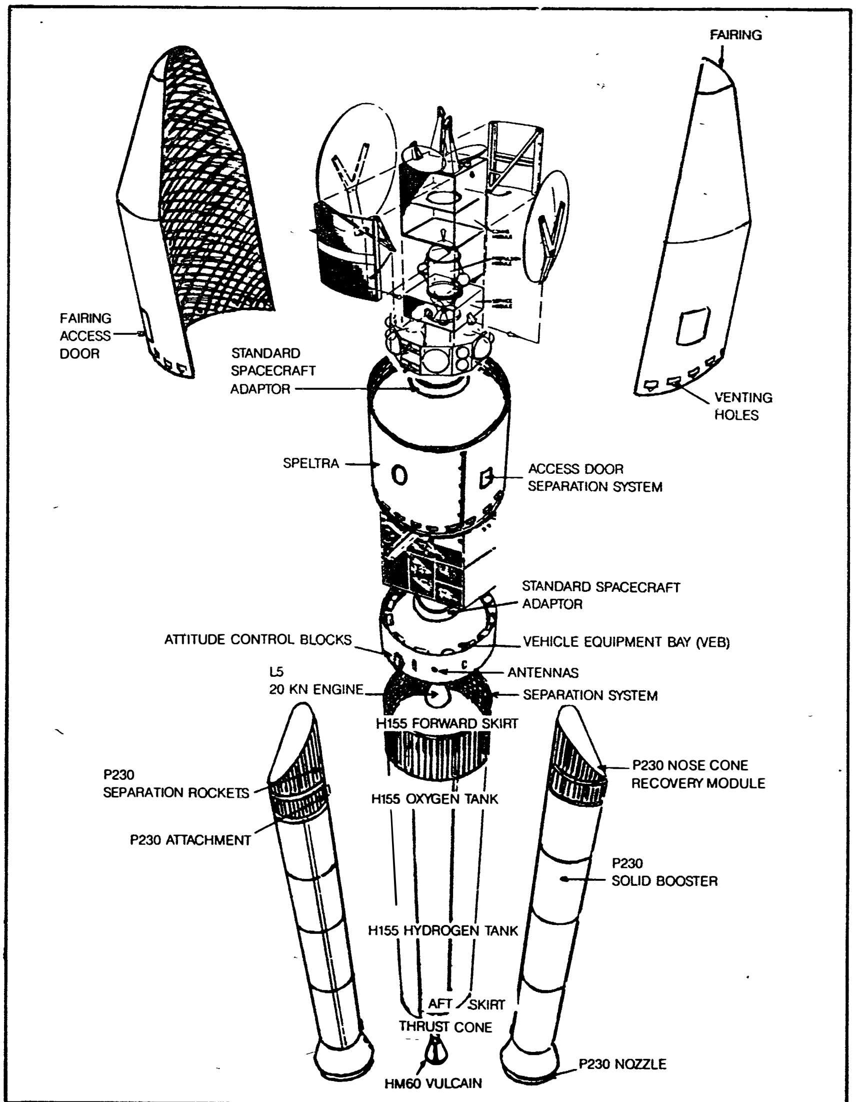
Launch costs are a major customer concern because they account for such a large part of the total cost of a satellite system and future business will inevitably go to the most economical systems.

A second customer concern, which has gained increased importance in the last two years, is that of reliability. Awareness has been sharpened by the incidence of Western launch failures and the increasing cost of the payloads themselves. High reliability is therefore demanded of Ariane 4's successor whether or not it should be cast into a man-carrying role. In a 1987 report released by CNES, the French national space agency, to ESA member states, a total mission reliability rate of 98 per cent was given for unmanned Ariane 5 missions, compared with 90 per cent for Ariane 3 and Ariane 4.

Ariane 5 To Fulfil Several Roles

As well as participating in the commercial satellite launch market, ESA plans to play a significant role in the international space station and associated platforms (i.e. the Man-Tended Free Flyer and the Polar Platform) through its Columbus Programme. This role, involving not only hardware development but also launch capability and provision of

Exploded view of the Ariane 5 launch vehicle. *ESA*



This report is based on an article entitled "Challenge '95 – The Ariane 5 Development Programme" by M. Vedrenne published in ESA Bulletin 52, November 1987.

Ariane 4 Set for Launch Debut

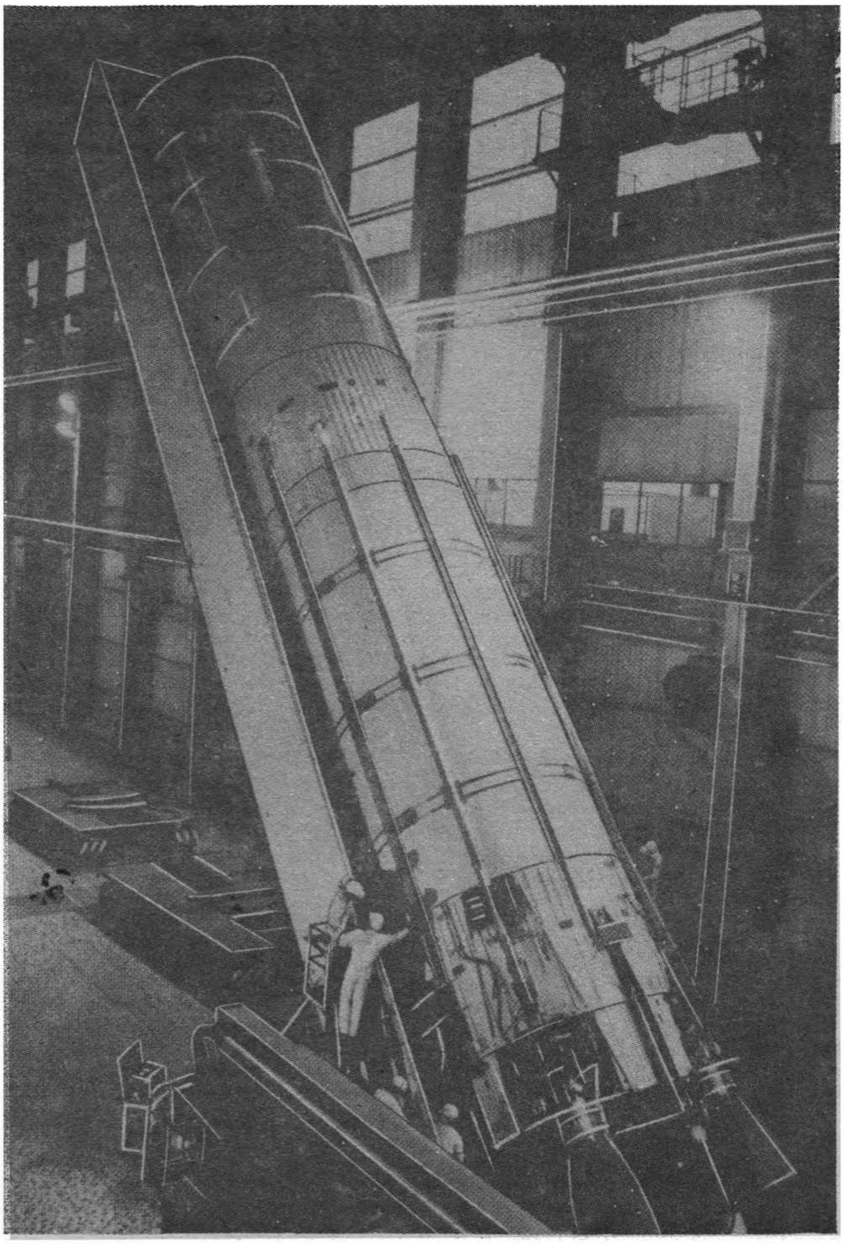
The first launch of an Ariane 4 (V401) which will carry the European Meteosat P2 weather satellite, the Amsat radio amateurs' satellite and the Panamsat communications satellite, is currently scheduled for late March or early April of this year.

In preparation for this launch, Ariane 4's first stage was delivered at Aerospatiale's Les Mureaux facility on November 3, 1987. Following the flight readiness review on November 6, authorisation was given for transportation to the launch site of the first and second stages, a set of the liquid-propellant strap-on boosters, the equipment bay and the dual launch external bearing structure (SPELDA). The solid-propellant strap-on boosters and fairing were already at Kourou and the third stage was scheduled to be conveyed by air in early January 1988.

The main differences between Ariane 3 and Ariane 4 are an increase in propellant capacity from 145 t to 226 t and the facility to strap on two or four liquid-propellant boosters.

Arianespace has so far placed an order for 21 Ariane 4s. To date there have been 11 Ariane 1s, already launched, and 17 Ariane 2s and 3s ordered, of which eight have been launched. By 1998 it is expected that a further 50 Ariane 4s will have been ordered leading to an impressive total of around 100 Ariane launches.

In view of the major part to be played by Ariane 4 in Europe's space programme over the next 10 years, the forthcoming launch is awaited with high hopes that it will result in a successful demonstration of the new system.



Picture: Engineers at work on the first stage of the first Ariane 4 launcher. This new first stage is 25 metres high, seven metres longer than its predecessors. It has a dry weight of 17 metric tons and will contain 226 tons of liquid propellants which will be burned in 214 seconds of flight.

manned services and operations will give Europe some measure of independence and autonomy in manned space flight with its own in-orbit infrastructure.

The development time-scale of the international space station is similar to that of Ariane 5 and the opportunity to cast Ariane 5 into the alternative role of the low-Earth orbit work-horse of Europe's Columbus Programme has not been missed. Performance-wise, Ariane 5 would be well suited to fulfil the dual tasks of putting the larger commercial satellites of the future into geostationary orbit and the heavier payloads of space station operations into low-Earth orbit. A third role for Ariane 5 would be that of launching commercial satellites into Sun-synchronous orbits.

According to CNES, comparable performance figures for the standard version of Ariane 5 to be most commonly used after 1995, are:

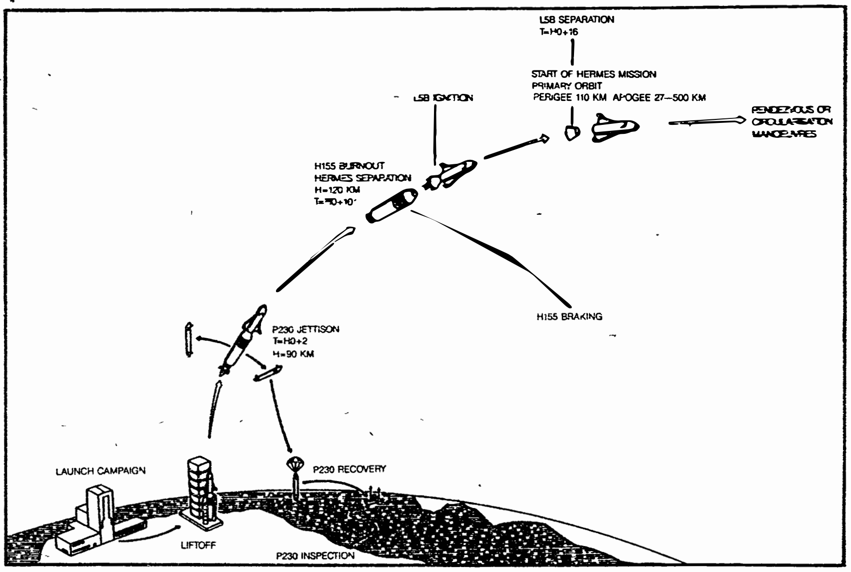
Mission	*Payload (tonnes)*
GTO (300 km x 36,000 km, quasi-equatorial)	6.8*
Sun-synchronous orbit (8700km, 98.6 degree inclination, e.g. the Columbus PPL element)	12
Circular orbit (550 km, 28.5-degree inclination, e.g. the Columbus MTFF element)	18
Hermes space plane (500 km circular orbit, 28.5 degree inclination)	21

*Reduced to 5.9t for a dual launch

Payload diameters up to 4.5 m may be accommodated with heights between 4 m and 10.5 m. Vehicles would be available for launch every five weeks from the new ELA 3 launch complex at Kourou.

In its GTO role, more than 80 per cent of missions are expected to be dual launches with a satellite of 2800-3200 kg weight coupled with one of 2200-2800 kg. The remainder are likely to be triple launches with one 2000 kg satellite coupled with two satellites of 1200-1600 kg. The aim is to make the cost of using Ariane 5 for a dual launch into GTO at least 10 per cent lower than that of using an Ariane 44L vehicle, assuming eight launches a year including four into GTO. On the basis of this target, Ariane 5 should provide a

EUROPEAN RENDEZVOUS



Flight sequence for an Ariane 5/Hermes launch. *ESA*

reduction of some 45 per cent in the cost-per-orbital kilogramme compared with Ariane 44L.

In its low-Earth orbit role, missions will most likely be single launches—the type of payload being difficult to combine and often requiring the full capacity of the launcher, as in the case of the Columbus elements.

Ariane 5 Configurations

The Ariane 5 launcher is made up of a lower section which is mission independent and an upper section which takes various forms according to mission requirements.

The lower section consists of solid and liquid propulsion units designated 2P230/H155. The solid unit comprises two large solid-propellant boosters (P230s), each containing 230t of grain and developing some 750t of thrust at lift-off with a burn-time of 120s. Their weight without the propellant is 39t. Recovery of the boosters for re-use is not envisaged because the economic benefits are considered marginal, but during qualification flights they will be recovered for inspection so that tolerances can be checked. The boosters will be transported from Italy to France by road in horizontal containers and then by ship from France directly to the Guiana Space Centre where docking facilities are to be built by ESA.

The liquid unit (H155) is the main cryogenic stage powered by the Vulcain/HM60 engine of 1.3t weight, which delivers 1,025kN for about 600s following ignition on the ground. The unit holds 155t of propellants (130t of liquid oxygen in the upper part and 25t of liquid hydrogen in the lower part) and has dimensions of 5.4 m diameter and 30 m height.

For unmanned missions, the upper section comprises a final propulsion stage, a vehicle equipment bay (VEB), a fairing and, if required, a Speltra payload-support structure. Speltra stands for Structure Porteuse Externe de Lancements Triples Ariane (external support structure for Ariane triple launches). It has a height of 5.8 m and weight of 900 kg. One Speltra enables two satellites to be accommodated and two Speltras fitted one on top of the other allows for a triple launch.

The final stage of propulsion (designated L5) uses 5.2t of N_2O_4 and MMH storable propellants, delivering 20 kN of thrust for up to 800s and being reignitable in flight. For geostationary missions the L5 enqine will be ignited immediately after H155 separation.

The equipment bay contains the electrical system which has a high degree of redundancy and the attitude control system which functions until the extinction of the L5 stage. The fairing is available in long and short versions, being either 20 m long and weighing 2.4t or 10.8 m long and weighing 1.4t. The short fairing is used for dual or triple launches (with one or two Speltra support structures) and either version may be used with single launches. The Columbus Programme elements constitute very special payloads in terms of size and mass and the long fairing has been planned to provide the volume needed for these and the accompanying special adapter.

For manned missions, the upper section will be the Hermes spaceplane mounted on an adapter which is fitted with an additional propulsion unit derived from the L5 engine. The launcher's powered flight will have two main phases. The initial part will be virtually identical for all missions, beginning with ignition of the HM60 Vulcain engine on the ground. Once this is functioning properly, the command is given to ignite the P230 solid boosters, leading to liftoff. At P230 burnout, the boosters are jettisoned and the H155 core stage continues powered flight on its own. Hermes houses the electrical equipment needed for flight control and guidance of the lower section since it wholly replaces the functions carried out by the vehicle equipment bay in the unmanned version.

Hermes is separated from the H155 at the end of the first phase and is then put into a transfer orbit using the propulsion unit housed in its adapter. After separation from this, the spaceplane circularises its orbit at the first apogee and commences manoeuvres demanded by its mission.

Ariane 5 Development Programme

Ariane 5's 10-year development programme started in January 1988 and concludes with the final Hermes in-flight test in late 1997.

Two other test flights are planned before A503 to validate the in-flight functioning of the entire Ariane 5 vehicle, the launch base and associated tracking facilities. These are:

Flight A501: A single launch into Sun-synchronous orbit with the upper section consisting of a long fairing.

Flight A502: Launch into GTO of three payloads with the upper section consisting of two Speltras and a short fairing.

The main development milestones for Ariane 5 are:

Start of development	1 January 1988
Preliminary design review of launcher stages and elements	1987 to 1990
Ground qualification of launcher stages and elements	1993 to 1994

Ferranti Mirrors Ready for Rosat Camera

A vital stage in the production of the UK's Wide Field X-ray ultraviolet (XUV) Camera, to be flown on the German Rosat satellite, has been completed by Ferranti.

The wide Field Camera is being developed by a consortium of five British space science groups from the University of Leicester, Mullard Space Science Laboratory, the University of Birmingham, Imperial College of Science and Technology and the Rutherford-Appleton Laboratory of the Science and Engineering Research Council.

The Rosat satellite was originally scheduled for launch on the US space shuttle in October of last year but delays in the Shuttle programme have led to Rosat being transferred to a NASA Thor Delta rocket. Launch is now scheduled for February 1990.

EUROPEAN RENDEZVOUS

End of system tests in Europe	1993
ELA 3 available	1992
First test flight	Early 1995
First operational flight	Early 1996
First in-flight test (Hermes mission)	Late 1997
End of development	1997

Ariane 5 Operational Phase

After the two qualification flights of the automatic version in 1995 (A501 and A502), Ariane 5 will be declared operational. The first commercial flight to put an automatic payload into orbit is planned for early 1996, and will consist of either conventional satellites or the Columbus Polar Platform.

After additional development work for manned flights and in-flight qualification for the first version of Hermes (H001) in late 1997, Ariane 5 will go into service for manned missions from 1998 onwards.

Until Ariane 5 is available operationally for automatic missions, operational launches of Ariane 4 are planned at a rate of eight per year to meet user demand. Timing of the decision will have to be a compromise between protecting users from delays or difficulties involved in Ariane 5's qualification and ensuring a rapid transition to solely Ariane 5 flights. The decision would be taken between flights A501 and A502; thereafter Ariane 4 production will be wound down and Ariane 5 production increased. The overall launch rate will accelerate from three launches in 1996 to reach the full rate of seven to nine launches in 1999, by which time the last Ariane 4s will have been launched.

Hermes in orbit.

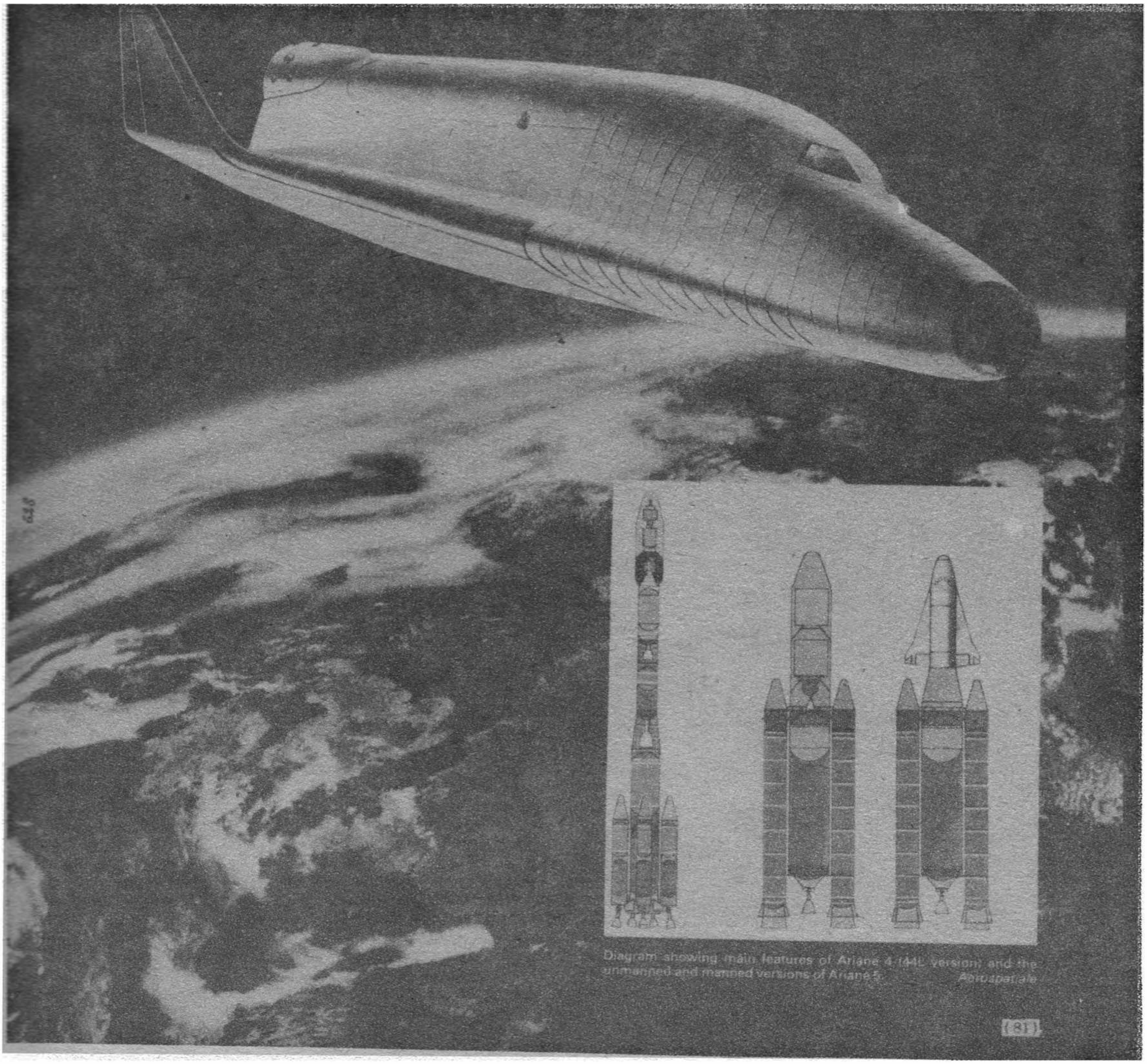
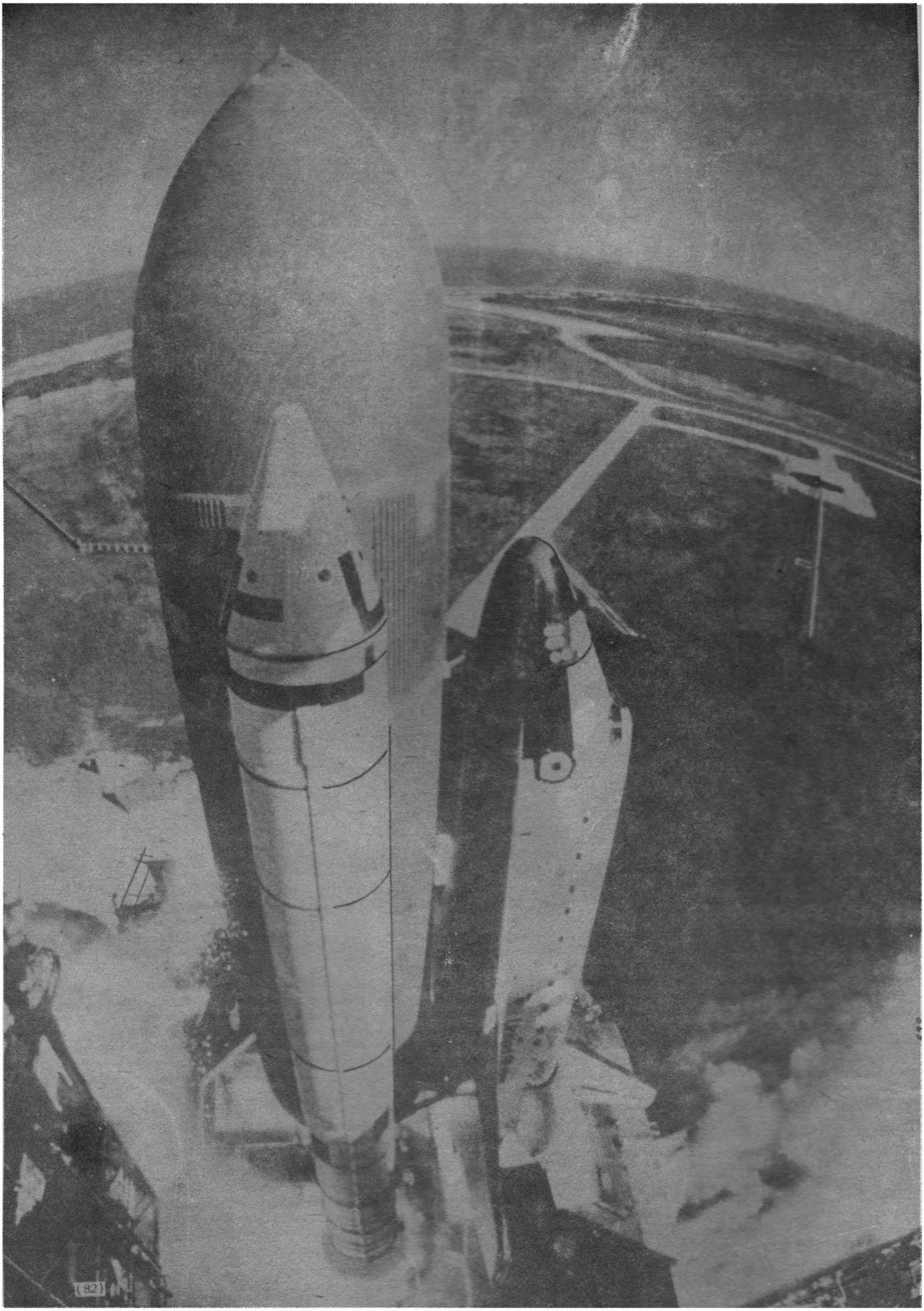


Diagram showing main features of Ariane 4 (44L version) and the unmanned and manned versions of Ariane 5. Aerospatiale



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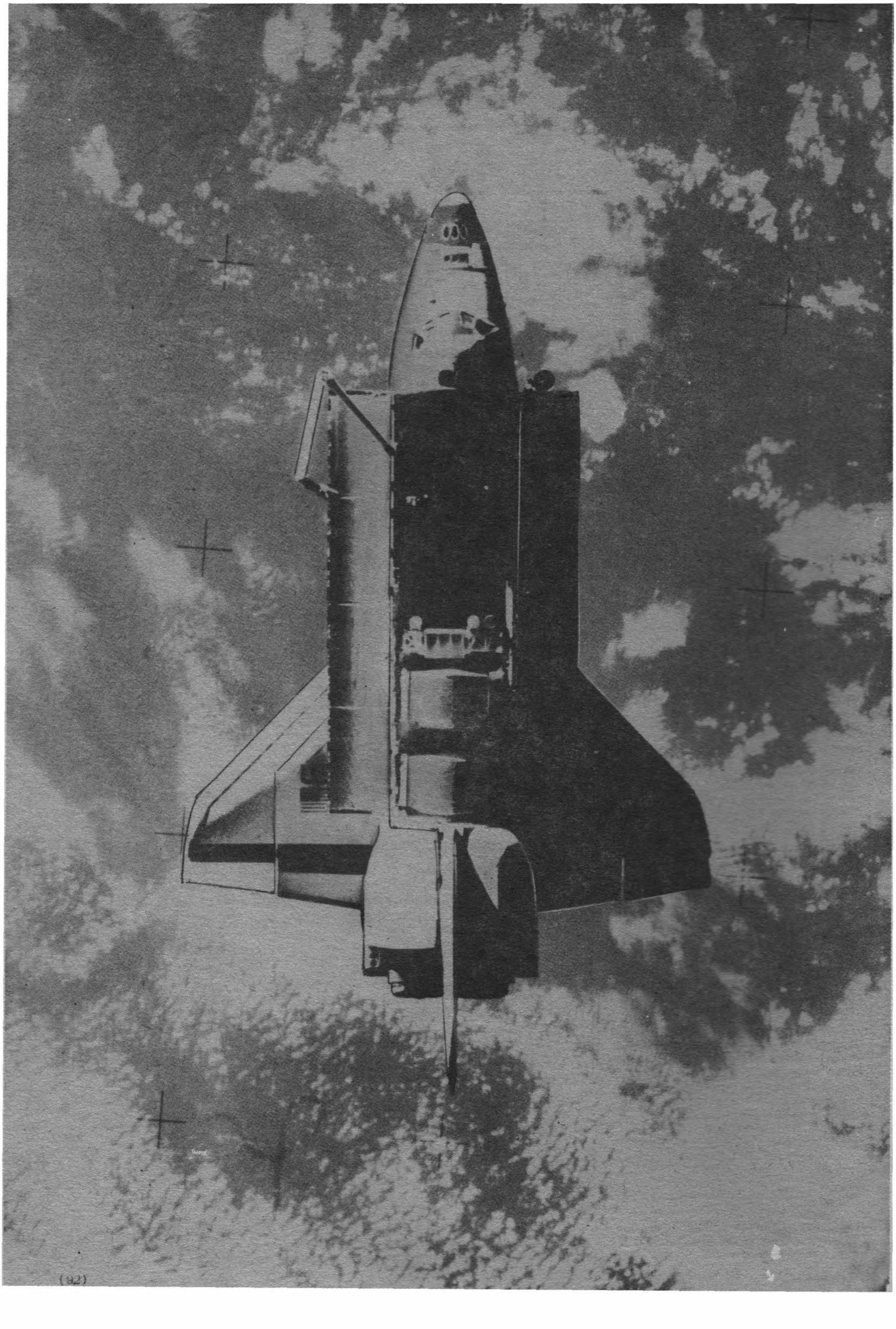
Front Cover: Dramatic painting of astronaut at work in space by *Dennis M. Davidson*, astronomical artist for the Hayden Planetarium, New York. NASA is currently in the process of selecting a new design for a space suit to be used on EVA work connected with the construction and operation of the international space station in the 1990s (see colour feature starting on p.96).



BORN AGAIN!

Second-hand Spacecraft are sometimes given a new lease of life

Spacecraft and space hardware have often been put to uses far removed from that originally intended. *Ralph D. Lorenz* casts his eye over some of the more notable cases of the past and considers some future possibilities.

Over the past 30 years much important work has been done to offset the high cost of exploring space by using space components from previous projects or by turning a spacecraft to a new mission after successful completion of its primary task. Scientists and engineers have put their ingenuity to work in many ways in developing effective and sometimes novel uses for space hardware.

In general, the larger a space programme the more spare hardware is left on its completion – particularly when the programme is cut short for financial reasons. But even when few spacecraft are built for launch, many components, used in testing to ensure everything works perfectly, are left. Consequently, the many prototypes, thermal, electrical and engineering models built before the flight model reaches completion can be 'cannibalised' for components.

The construction of OV-105, the yet-to-be-named replacement for the space shuttle orbiter Challenger, is made easier by the fact that many of the components and sub-systems had already been made. Examples of the migration of components between programmes include CRAF (see below) and the British satellite UoSAT-1. The rechargeable Nickel-Cadmium batteries that found their way onto UoSAT were surplus NASA cells from the ITOS programme. The Transit navigation satellite programme involved many small satellites launched over several years. Some of the craft left over were modified for other purposes – such as Hilat, a high-latitude ionospheric research satellite. A more recent example is Polar Bear (Beacon Explorer/Auroral Research) which was made from a Transit satellite that had spent eight years in a museum (***Spaceflight***, January 1987, p.11).

Some of the components used in space research do not originate in the space industry. Aries sounding rockets use solid rocket motors from unused Minuteman missiles, although the reliability of these sounding rockets has been poor. Of course, Titan ICBMs have been refurbished as launch vehicles too.

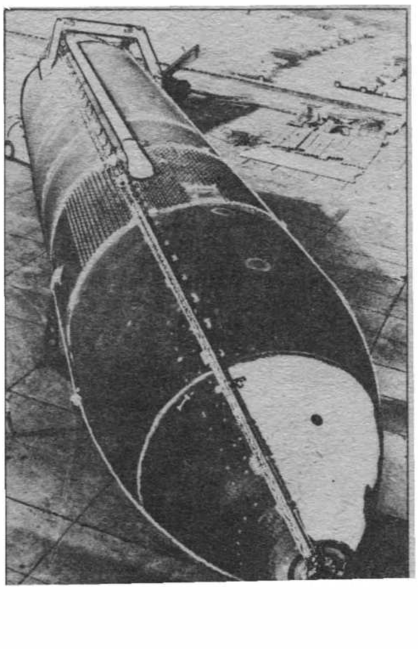
Spacecraft already launched can also be used for other purposes which may be at first sight completely unrelated to their primary missions. The Apollo 12 Lunar Module ascent stage, once its crew had transferred to the Command Module after lifting off from the lunar surface, was dropped back onto the Moon so that its impact could be used to calibrate seismic instruments left on the surface.

The Russian Progress freighters, which carry supplies and equipment to manned space stations, are de-orbited and burn up in the Earth's atmosphere after they are emptied. Before being undocked from the station and sent to a fiery end, the craft is filled with unwanted equipment and waste, thereby preventing a build-up of rubbish on board the station. The Kvant astrophysical module which was linked to the Mir station earlier this year, as well as being fitted with instruments and equipment, also extends the available living space of the station. This empty space was put to good use on its launch, since the module was packed with 2.5 tonnes of equipment for the cosmonauts. Thus Kvant served as a freighter as well as a laboratory.

Among the many examples of spacecraft re-utilisation, the more exotic include those used to observe comets. The first comet flyby was made by the International Cometary Explorer (ICE). It was launched in 1978 as ISEE-3 (one of three craft in the International Sun-Earth Explorer programme) to monitor the solar wind upstream of the Earth. After completing its mission in good health it was then used to make similar studies 'downwind' of the Earth, in the 'magnetotail'. Dr Robert Farquar of the NASA Goddard Space Flight Center suggested a series of complex gravity-assist maneouvres as low as 120 km above the Moon to send the craft on to comet Giacobini-Zinner where it made useful observations.

As well as being studied by European, Japanese and Soviet probes, Halley's comet was observed by many telescopes on and in orbit around the Earth. Interestingly, the comet's passage (and that of Encke's comet a year earlier) was viewed with an ultraviolet telescope on board a spacecraft in orbit around another planet. The US Pioneer Venus Orbiter, which has circled Venus since 1978 and has stayed in remarka-

The Challenger space shuttle in Earth orbit during STS-7 in 1983 as viewed by a 70 mm camera onboard the free-flying SPAS-01 pallet satellite developed by MBB in West Germany. Challenger, which completed nine successful missions before its destruction in January 1986, was built originally as a test vehicle. Construction of its replacement is being made easier by the use of many parts originally designated as spares for the orbiter fleet. *NASA*



The US space shuttle external tank (ET) attains around 98 per cent of the velocity needed to reach orbit before being discarded to burn up in the atmosphere. A longer burn on the shuttle's main engines could easily place the tank in orbit where uses may range from a gamma ray telescope to an orbital space station module. *NASA*

BORN AGAIN!

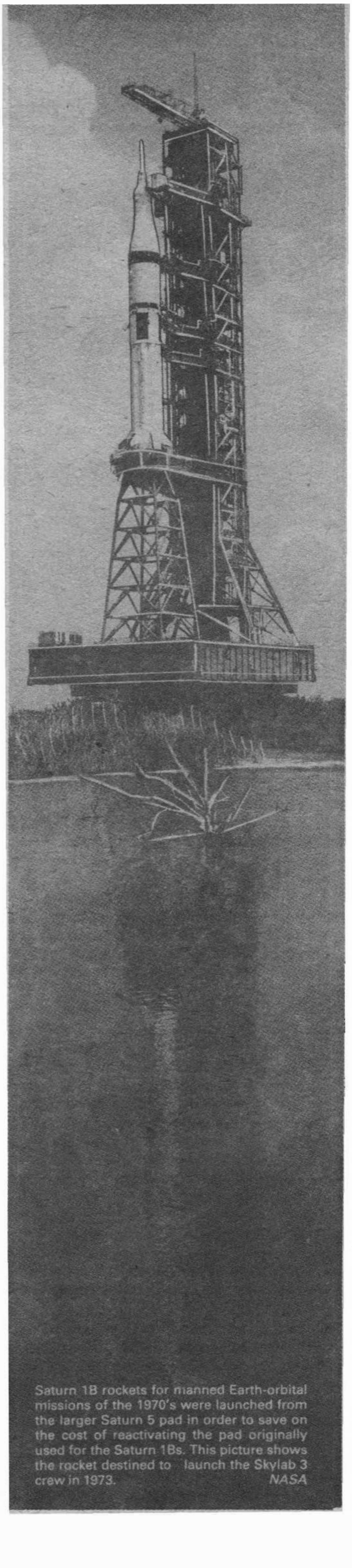
bly good condition, used its telescope originally to analyse the Venusian atmosphere, before using it to study gases being blown off comets. Ultraviolet observations of other planetary atmosphere have been made by UV spectrometers on the Voyager probes to the outer Solar System. During the long, quiet interplanetary cruise periods, these craft have been used as observatories, turning their UV instruments starwards to complement observations by other craft.

Several of the probes which visited Halley's comet may make further encounters. ESA's Giotto is set to make a close pass of comet Grigg-Skjellerup in 1992. If the camera is operational (it may have been damaged during the hazardous Halley encounter) it will provide good pictures (the flyby speed is lower and the approach geometry will allow a lower camera offset angle to be used, so high-quality pictures can be made throughout the encounter). In addition, when Giotto is on the opposite side of the Sun to the Earth this winter, it may be used to make radio sounding of the electron distribution in the solar corona.

It has recently been suggested by NASA that Japan's Halley probe, Sakigake, could be diverted (again using Earth gravity-assists) to another comet in 1996. Also, the two Soviet Vega craft (which had already visited Venus, dropping balloons and landers before moving on to Halley) may be sent to rendezvous with a comet or perhaps an asteroid (although before the Halley encounter, mission planners were too cautious to assign future objectives for the craft). In the event, they were not too badly damaged, suffering solar panel degradation and loss of some experiments, and so should be able to do further work.

One proposed US mission, the Comet Rendezvous/Asteroid Flyby (CRAF), will study an asteroid en route to a comet rendezvous. Costs of spacecraft for the mission are being held down by using spare parts from previous missions. Many components, such as the Radio-isotope Thermoelectric Generator (RTG), the magnetometer boom and the rocket engine will be leftovers from the Galileo mission to Jupiter. Other items such as high-gain antennae from the Voyager or Viking missions will also be used.

Many readers may be familiar with the techniques of Very Long Baseline Interferometry (VLBI) in which two or more widely separated (but electronically linked) radio telescopes are used to derive the resolving power of a single telescope with a huge aperture (equal to the separation distance). Currently the separation of telescopes is limited by the diameter of the Earth, but a telescope onboard a spacecraft some distance from Earth would allow observtions of far greater resolution to be made. Plans exist for a satellite, Quasat, with a 15 m antenna to study



Saturn 1B rockets for manned Earth-orbital missions of the 1970's were launched from the larger Saturn 5 pad in order to save on the cost of reactivating the pad originally used for the Saturn 1Bs. This picture shows the rocket destined to launch the Skylab 3 crew in 1973. *NASA*

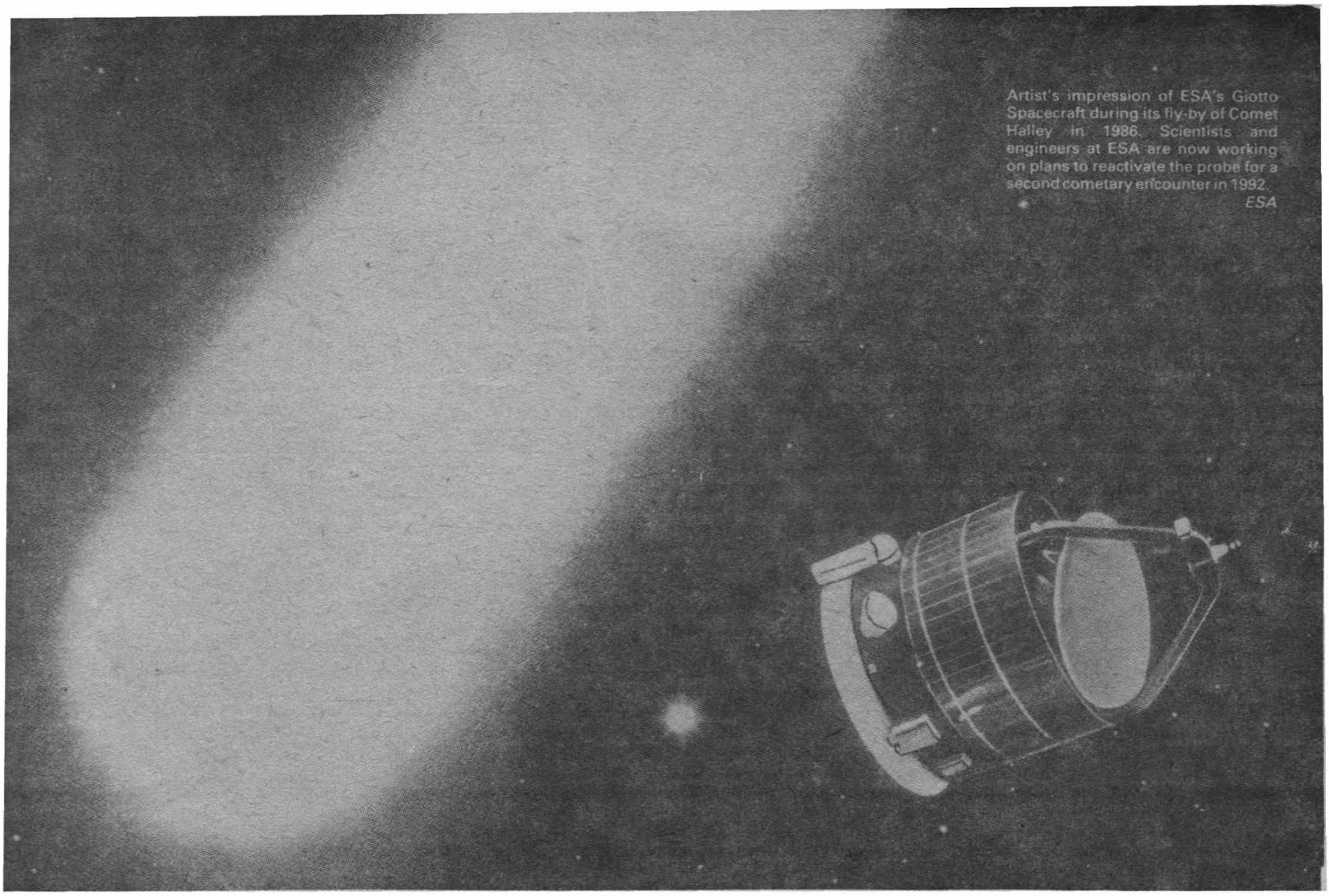
quasars and other radio sources: its orbit with a 15,000 km apogee would allow resolutions five times better than those obtainable on Earth. The USSR plans a similar satellite, Radioastron, with a 10 m antenna but a higher, 70,000 km apogee. Although the Quasat and Radioastron craft will not be in orbit for several years, the technique of using a spaceborne radio telescope for interferometric observations has already been used, thereby proving its feasibility. The satellite used was NASA's only operational satellite in the Tracking and Data Relay System, namely TDRS-1. This craft, which limped into geostationary orbit using its station-keeping thrusters after its booster failed, carries, among other antennae, two large (4.9m) S-band dishes. One of these dishes was used in conjunction with radio telescopes in Australia and Japan late last year. Although the steerability of the antenna was limited to 30 degress off nadir (nadir is the line joining the satellite to the centre of the Earth) thereby limiting the effective length of the basline, the initial experiments with TDRS have yielded images of three quasars with better resolution than is possible using ground-based telescopes alone.

Manned Missions

Costs can be reduced in manned space flight programmes too by reuse of spacecraft or components. Although the US space shuttle was rightly hailed as the world's first reuseable space transportation system, components were reused in the earlier Apollo and Gemini programmes. Seats, whole instrument panels and such items as the 'space sextant' have all been flown several times (it is interesting to consider that perhaps the most reuseable component of a manned space system is also its most fragile – its human crew.)

The Skylab space station was built from a Saturn IVB rocket stage and spare Apollo hardware. Crew facilities were fitted inside the S-IVB's cavernous hydrogen tank and docking and other modules were attached. The EVA hatch was one that had been cannibalised from a spare Gemini capsule. The craft used to take astronauts to the station were Apollo Command and Service Modules (CSMs) that carried extra propellant, batteries and water for their long stay in orbit. The CSMs were launched toward Skylab on Saturn IB rockets, which had not been used for several years. In order to save the time and cost of reactivating the old Saturn IB launch pad, the Saturn 5 pad 39B was used instead. The problem that the 1B was considerably smaller than the colossal Saturn 5 Moon rocket was solved by standing the 1Bs on a pedestal (thus allowing umbilicals and fuel lines to reach the correct points on the rocket).

Today, the US space shuttle is the most reuseable spacecraft to be built,



Artist's impression of ESA's Giotto Spacecraft during its fly-by of Comet Halley in 1986. Scientists and engineers at ESA are now working on plans to reactivate the probe for a second cometary encounter in 1992.
ESA

with only the external tank (ET) being lost. With several shuttles in the fleet, all with common components, turn-around times can be improved by 'sharing' parts: for example, a flight-ready set of OMS pods might be fitted onto the shuttle on the next flight, instead of the vehicle for which they were originally intended.

Also worthy of note is the fact that the orbiter Challenger, which undertook nine successful missions before its unfortunate destruction, was built originally as a test vehicle.

In the early '70s, when the space shuttle was still being designed, until a very short time before the design was frozen and construction began, the ET was intended to be taken into orbit along with the crewed orbiter. Drawings showed the ET with a small retro motor to bring it back down. The current configuration involves discarding the ET just before attaining orbit, but the ET has around 98 per cent of orbital velocity. Thus all that needs to be done in order to take the potentially useful tank into orbit is to burn the shuttle's main engines a little longer (there is plenty of room in the ET to accommodate the extra propellants required.)

Existing proposals include building a gamma ray telescope inside the ET. A company in the US, External Tanks Corp., has come up with a commerical space station built with two ETs linked by an auxiliary module providing life support, power and docking facilities. The vast volume of the station would be leased to users on an annual basis (users would include such groups as firms conducting space manufacturing operations). The shuttle ET certainly has such promise that it deserves to be used as an orbital module. Failure to make use of its potential would be a great waste.

Failure to exploit the potential of the external tank, which could be placed in orbit by burning the main engines longer, would be a great waste.

Several proposals have been made for heavy-lift launch vehicles using existing components to save development costs. A United Technologies design is essentially a space shuttle stack (ET plus two solid boosters) with a cargo pod and propulsion module instead of the manned orbiter. The propulsion module would use Space Shuttle Main Engines. A Boeing/Hughes idea, the Jarvis booster, is a more conventional-looking rocket, with its body made by the same tooling as that used to make the ET. The original plan was to use left-over rocket engines from the Apollo programme, but the design has now been changed to use shuttle engines.

Many other major items of Apollo hardware are still around, in museums or storage facilities both in the USA and elsewhere. It would be possible to modify one of the three remaining Apollo command modules for use as a crew escape vehicle ('lifeboat') on the US International space station.

When man returns to the Moon, perhaps early next century, he will take with him vehicles with which to travel over the surface and to shift lunar soil (regolith) to use as shielding and in lunar factories. Although he will take these lunar vehicles with him, there are already three Apollo Lunar Roving Vehicles (LRVs) on the Moon's surface. Designed to cover about 90 km, not one was driven even half this distance. The LRVs' batteries will undoubtedly be inoperable after their long stay in the harsh lunar environment and other systems will probably need attention. However, there seems no reason why, with a new set of batteries and a little work, they could not be restored to operational status. Attempts to 'revive' a LRV would make an interesting experiment on the long-term effects of the lunar environment. Performance evaluation exercises on a reactivated LRV could also become a popular recreational activity for future lunar astronauts!

This article has attempted to show space hardware has, is, and will be used in ways that are not at first obvious. It is due to the skill and vision of those involved in the world's space programmes that such progress can be made with the often limited resources available.

Acknowledgement During the preparation of this article, various issues of *Spaceflight*, *Aviation Week* and *Space Technology* and *Flight International* magazines were consulted, among other sources. The author would also like to thank *Andrew Wilson* for providing much useful information

INTERNATIONAL SPACE REPORT

A monthly review of space news and events.

New Space Suit Designs on Test

NASA is evaluating the potential of two new space suit designs for use in extravehicular activities around the international space station.

Engineers at the Ames Research Center in California have developed the AX-5, a hard metallic suit, while a parallel study at the Johnson Space Center in Houston has come up with the Zero Pre-breathe Suit (ZPS) Mk 3, employing both hard and soft elements.

The AX-5 is made of aluminum and contains no fabric or soft parts. The suit will provide extremely high reliability, vastly reduce maintenance and enhance mobility and comfort. It can operate at up to normal atmospheric pressure and will shield against radiation and impact from small meteorites and space debris.

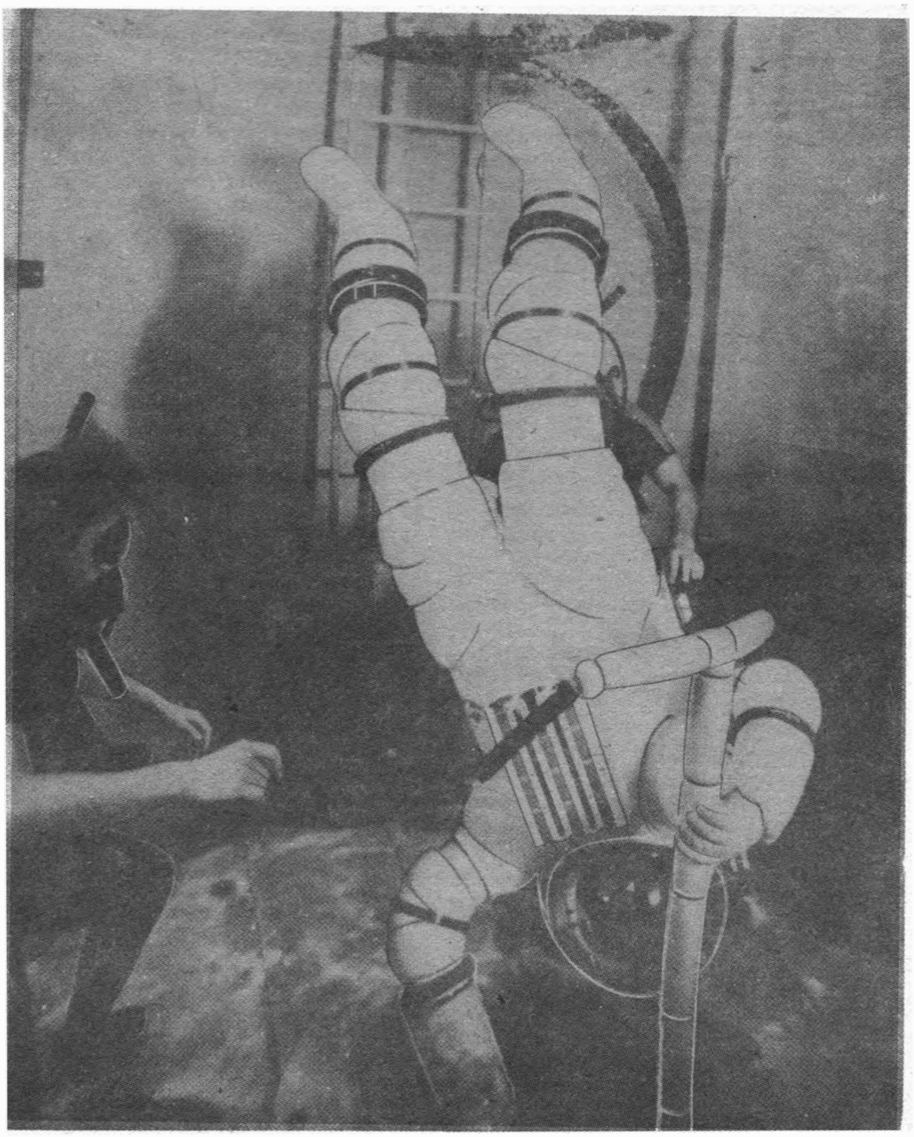
The AX-5 was designed to meet space station specifications but it can be modified for use on other Earth-orbiting missions or for interplanetary missions, such as a trip to Mars. The suit was developed at NASA Ames by spacesuit designer Hubert C. "Vic" Vykukal. "The hard suit will enable us to use current aerospace techniques all along the way, from initial design tests to maintenance," he said.

Mobility of the AX-5 is achieved by a unique arrangement of rotary bearings at the joints, which allows for a nearly full range of astronaut motion. Effort involved in working in the suit is minimised by this design because the suit maintains a constant volume and, hence, a constant internal pressure, no matter how it is flexed.

The suit will be able to operate for several years in space with just minimal maintenance and because the AX-5 is modular, any one part which needs to be serviced can easily be removed and replaced on-board the space station. The current operational suit requires a major overhaul on Earth after every mission and 30 to 50 hours of use.

At the end of last year, in the first of a year-long series of studies, the spacesuit was tested by immersion in water to simulate weightlessness at Ames' Neutral Buoyancy Test Facility. NASA astronauts are now continuing these studies in an extensive series of tests at the Johnson Space Center Weightless Environment Test Facility. Comfort, mobility and performance in simulated space missions will be evaluated.

Main picture: Research scientist Vic Vykukal is lowered into the neutral buouancy test facility at Ames for testing (insets) of the AX-5 all-metallic space suit. *NASA/AMES*



Manoeuvrability will be a key feature of the final design selected by NASA. The T-shaped device being clutched by Vykukal's right hand is placed in the nine foot deep tank to help control movement. *NASA/AMES*

Since the hard material that the AX-5 is made from is dense, it will provide an effective shield against radiation, while minimising bulk. The hard structure will also provide protection against impact from micrometeoroids and human-made "space junk" floating in Earth orbit.

The spacesuit will be coated with a microscopically-thin outer layer, which may be pure gold or aluminum, to protect against corrosion and to provide good thermal insulation (the coating will be so thin that an entire spacesuit would require less gold than a necklace). In the space station environment, the suit may be exposed to corrosive, toxic fuels such as hydrazine, as well as to ambient atomic oxygen in space, which is highly reactive. Gold, one of the most inert elements known, can tolerate these substances.

Space suits must be built to with-

INTERNATIONAL SPACE REPORT

SATELLITE DIGEST – 210

Robert D. Christy

Continued from the February 1988 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

PROGRESS 33, 1987-94A, 18568

Launched: 2347*, 20 November 1987 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carring a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried fuel and supplies to the resident crew of Mir/Kvant. It docked with Kvant's rear port at 0139 on 23 November. It undocked at 0816 on 19 December, and its retro-rocket was fired later the same day, leading to a destructive re-entry above the Pacific Ocean.
Orbit: Initially 187 x 249 km, 88.81 min, 51.66 deg, then manoeuvered to 326 x 343 km, 91.16 min, 51.64 deg for docking with Mir/Kvant.

TV-SAT 1, 1987-95A, 18570

Launched: 0219*, 21 November 1987 from Kourou by Ariane 2 (V-20).
Spacecraft data: Three-axis stabilised, cuboid-shaped body, approx 2 x 2 x 2.5 m, with a twin panel solar array with a span of 20m. One panel failed to deploy on reaching orbit.
Mission: West German, television direct broadcasting satellite. Its capacity has been curtailed by the non-deployment of one solar panel.
Orbit: Geosynchronous above 19 degrees west longitude.

COSMOS 1897, 1987-96A, 18575

Launched: 0128, 26 November 1987 from Tyuratam by D-1-e.
Spacecraft data: A stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Luch series communications satellite providing continuous telephone, telegraphic and television links both within the USSR and abroad. It may also be providing tracking support to Earth orbiting spacecraft by providing radio coverage while they are out of communication with normal ground stations.
Orbit: Geosynchronous above 85 degrees west longitude.

USA 28, 1987-97A, 18583

Launched: 0327*, 29 November 1987 from Cape Canaveral by Titan 34D + IUS.
Spacecraft data: not available.
Mission: Defence Support Program satellite monitoring Soviet ballistic missile launches.
Orbit: Geosynchronous.

COSMOS 1898, 1987-98A, 18585.

Launched: 1420, 1 December 1987 from Plesetsk by C-1.
Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 778 x 811 km, 100.80 min, 74.01 deg.

COSMOS 1899, 1987-99A, 18625

Launched: 0850, 7 December 1987 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 208 x 302 km, 89.63 min, 70.39 deg.

UPDATES:

1987-43 launch, USA 22-25 was a launch in the US Navy 'White Cloud' programme using an Atlas-M rocket from Vandenberg, not Cape Canaveral as listed. The satellites operate by detecting radio-signals, rather than reflected radar waves (acknowledgement to Joel Powell for pointing this out).
19876-59A, the largest fragment of COSMOS 1866 decayed on 5 November after 119 days.
1987-33A, COSMOS 1836 re-entered on 2 December after 230 days.
1987-85A, COSMOS 1893 re-entered on 16 December after 55 days.

Continued from previous page

stand enormous temperature fluctuation and the coatings will also protect against the severe thermal environment of space. In Earth orbit and without protection, the side of the suit facing the Sun may reach searing 400 degree F temperatures, while the other side, facing deep space, could get as cold as -250 degrees F.

Like its predecessor the AX-3, the first high-pressure spacesuit prototype, the AX-5 can operate at upto normal Earth atmospheric pressure of 14.7 pounds per square inch (psi). However, current space station guidelines call for a lower pressure of 8.3 psi to be used to allow greater mobility for the hands, although suitable gloves that can allow operations at pressures above 4.3 psi have yet to be developed.

Both prototype suits are entered through a hatch in the rear, with the legs put in first, followed by the upper part of the body. The AX-5 has joints permitting movement at the shoulder, elbow, hip, knee and ankle. Between the joints, rings of various sizes can be added, allowing the suit to fit people ranging from four feet 10 inches to seven feet in height. The suit has a 13 inch diameter helmet, allowing wearers to turn their heads for a wide field of view.

Like other advanced spacesuits, which operate at 8.3 psi and above, the AX-5 eliminates the breathing of pure oxygen to adapt the body before entering a low-pressure environment. Prebreathing which can take up to five hours with low-pressure suits, prevents the bends, a serious condition in which dissolved nitrogen in the blood bubbles out at low pressure.

As in all NASA spacesuits since Apollo, thermal control of the AX-5 will be maintained by a separate backpack which controls a liquid coolant garment, a network of fine tubes of flowing water worn beneath the spacesuit. The backpack also supplies gases for breathing, and cleanses the air of exhaled carbon dioxide and moisture.

Imperial Space Station

NASA has decided not to use metric measurements for the space station programme. Instead, it will be designed using the English system of measurement because, NASA says, mistakes in mentally converting metric measurements could endanger the crew, particularly during an emergency.

Astronauts Demand Extra Booster Test

US astronauts and other space agency officials have persuaded NASA to include an additional booster test in the series of full-scale firings planned before the space shuttle is cleared to resume operations.

Only two more full-scale tests were officially required but a third is now to be carried out following the request from astronauts and other officials for additional data.

NASA has officially targeted August 1988 for the launch of the first US manned space shuttle flight in more than 30 months. Richard Truly, NASA associate administrator for space flight, stated on January 27 that a specific launch date of August 4 had been set for internal planning purposes but this may be adjusted as various elements and test analysis are assessed.

The space shuttle Discovery is now scheduled to be rolled out to the Kennedy Space Center launch site on May 13 and its main engines test fired on the pad exactly one month later.

Truly told the US House Committee on Science, Space and Technology, that he was very pleased with the progress of the shuttle recovery programme, that results of the test firings of the shuttle's redesigned booster rocket "are very gratifying" and that the shuttle's three main engines have been tested by the manufacturer and delivered to the Kennedy Space Center.

Space shuttle launch date is now set for early August.

"My personal opinion is that the space shuttle recovery programme is very stable and I think that we have struck the proper balance between emphasis on safety and quality and also our need to get back into flight", Truly said.

The NASA official said he had been concerned about the implication made by news articles and by some members of Congress that the space agency is putting too much emphasis on a launch schedule at the expanse of safety.

"I want to say again that this is not true. Safety is first. But we feel a very strong need in this country to get the shuttle programme back into flight. And so we will push to do that," he said.

Discovery was originally scheduled to blast off on June 2, but the failure of the booster rocket's nozzle "boot ring" (***Spaceflight***, February 1988, p.83) during a test firing in December has further delayed the flight.

The boot ring protects a flexible bearing assembly that allows the rocket's nozzle to swing back and forth for steering during the first two minutes of flight. Truly said NASA officials have decided to rely on a back-up version of the boot ring design that was successfully tested in an August booster firing.

John Thirkill, vice president for space operations at Morton Thiokol, the manufacturer of the SRBs said that at no time was the shuttle's redesigned booster rocket in danger of failing or malfunctioning because of the boot ring failure.

Thirkill explained that actual failure occurred a couple of seconds after the test firing was over and added: "Had this been an actual flight, there would have been no detectable effect on the (rocket) motor or vehicle performance."

The scheduled dates for the booster tests at the Morton Thiokol headquarters in Utah are April 7, June 9 and July 6. The July 6 test will feature an intentional built-in flaw that will permit hot gas to leak all the way to the primary O-ring seal of the rocket's fuel segment joint to prove that the new design can withstand major failures.

Truly said that recently discovered weld problems in the shuttle's main engines and booster rockets appear relatively easy to correct and should have no impact on the August launch date.

NASA engineers, using new ultrasonic inspection techniques, discovered defective welds in assemblies at the base of the shuttle boosters that are used to help anchor the rocket's "aft skirts" to the launch pad. The engineers also discovered defective welds in a metal seal used in the shuttle's liquid-fuelled main engines.

But Truly reported that the aft-skirt flaw is "no problem" because it is located in a low-stress area that engineers can repair. As for the main engine welds, Truly said engineers have plenty of time to replace the defective fuel pumps before the planned shuttle launch.

Astronaut Memorial Chosen

A "Space Mirror" has been declared the winning concept in an Astronaut Memorial design competition. The design, chosen for the proposed memorial to America's fallen astronauts, utilises a 40 by 50 foot rectangle of thin granite veneer, through which the names of 14 astronauts will be cut. The smooth granite surface is to be set up so as to reflect the sky and a proposed tracking system would allow the granite surface to follow the Sun during the day, providing optimal lighting of the astronaut names.

In addition to the seven astronauts who died in the Challenger explosion on January 28, 1986 (Dick Scobee, Michael Smith, Judith Resnik, Ellison Onizuka, Ronald McNair, Gregory Jarvis and Christa McAuliffe) the names of seven astronauts who died in aircraft and ground testing accidents are also inscribed.

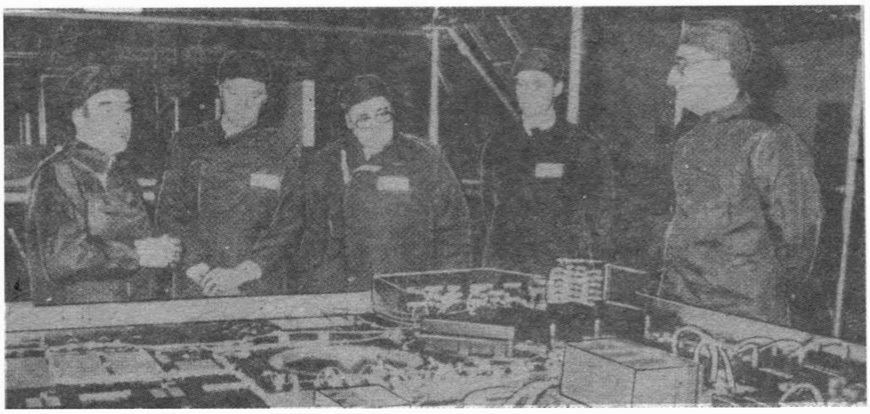
Theodore Freeman was killed in an aircraft crash on October 31, 1964; Charles Bassett and Elliot See were killed in an aircraft crash on February 28, 1966 while en route to training in support of their Geminii IX mission; Clifton Williams was killed in an aircraft accident on October 5, 1967; and Virgil "Gus" Grissom, Ed White, and Roger Chaffee were killed in the Apollo capsule fire on January 27, 1967.

The proposed site for the memorial is at the Kennedy Space Center in Florida and it is planned to have the memorial in place at the visitor information centre there by early 1990.

Japanese Comsat Lift-Off

Launch of Japan's CS-3a communications satellite by an H-1 vehicle from the Tanegashima Space Centre was scheduled for between 18.30 and 20.30 (JST) on February 16.

The 550 kg satellite, spin-stabilised and with an operational life-time in geostationary orbit of seven years, is the latest in a series developed since the first was launched in 1977. CS-3a is designed to meet increasing and diversifying communications demands and to develop advanced satellite communications technologies.



Industry Fact – Finding Visit

The UK government, strongly criticised for its space policy in a new report (see p. 124), has been canvassing the views of British industry involved in space.

John Butcher MP, Under-Secretary of State for Information Technology, was at the Marconi Space Systems plant in Portsmouth recently to view and discuss current work.

Pictured examining the specilised services payload for the Olympus communications satellite are: (from left) Roger Kenyon (Marconi), John Butcher, Clifford Nicholas (BNSC), Richard Wignall (managing director of MSS) and Michael Painter (business development manager of MSS).

First Titan IV at Launch Complex

The arrival of the first Titan IV at Cape Canaveral's Launch Complex 41 was celebrated at a ceremony which also marked the reopening of the launch complex following modification and refurbishment, *writes Roelof L. Shuiling.* **Air Force Secretary Edward C. Aldredge performed the re-opening ceremony on January 14, two days after the arrival of the first Titan IV's upper and lower core stages. The first Titan IV launch is scheduled for this autumn.**

In his remarks, Secretary Aldredge noted that the goal of the United States' military space programme was the ability to maintain a capability for assured mission operations, which he defined as assured on-orbit operations and an assured launch capability.

He indicated that the space launch recovery programme was now well on its way and he cited the Titan IV and the recent successes of the Titan 34D as examples. Aldredge also called for consistency in the support of the space programme.

Launch Complex 41 was last used in September 1977, when the final Titan-Centaur launched NASA's Voyager One planetary probe. The complex has just completed a two year refurbishment and modification programme under a contract awarded to Martin Marietta Corporation. The work included increasing the height of the Mobile Service Tower by 20 feet to accommodate the 204 foot tall Titan IV which is 50 feet taller than the Titan 34D. In addition, both the Mobile Service Tower and the massive Umbilical Tower were completely inspected and refurbished after years of inactivity.

There are now two Titan launch complexes at Cape Canaveral. The Titan IV will use complex 41 and Launch Complex 40 is in use by the Titan 34D. Both of these are supported by the Vertical Integration Building, where the liquid fuel cores of the Titans are built up, and by the Solid Motor Assembly Building, where the solid rocket boosters are built up and attached to the Titan cores. The launch vehicles are then carried to their launch pads along a five mile rail-road which moves both the launch platform and the vertical Titan at the same time.

The Titan IV, the latest addition to the family of Titan launch vehicles, is an improved version of the Titan 34D with stretched first and second stages, seven-segment solid rocket boosters and a 16.7 foot diameter payload fairing. The Titan IV can utilise either the Centaur G-Prime or the IUS upper stage. In February of 1985 Martin Marietta was chosen by the Air Force to build and launch ten Titan IVs and in August of 1986 this programme was expanded to 23 vehicles.

The Titan IV with the Centaur is capable of placing 10,000 pounds into geosynchronous orbit, 39,000 pounds into a 28.6 degree low-Earth orbit, or 32,000 pounds into a low-Earth polar orbit. In 1991 an upgrade of the solid rocket motors will be incorporated which will enhance performance by approximately 25 per cent. The Titan IV is powered by liquid fuelled core engines burning Aerozine 50 and Nitrogen Tetroxide hypergolic propellants, and by solid rocket boosters burning powdered aluminum fuel and ammonium perchlorate oxidizer.

The two solid rocket boosters are manufactured by the United Technologies Chemical Systems Division and provide 1.6 million pounds of thrust from each booster for two minutes. Aerojet Techsystems provide the LR87-AJ-11A first stage powerplant which delivers 548,000 pounds of thrust for 200 seconds, and the second stage LR91-AJ-11A engine which provides 105,000 pounds of thrust for 245 seconds. McDonnell Douglas is the payload fairing manufacturer and Delco Systems provides the inertial guidance system. Martin Marietta is responsible to the Air Force for overall production and launch services.

Newcomers on the Space Scene

Pakistan is preparing for launch this summer of a small technological spacecraft. Named BADR-A and weighing some 75 kg, this satellite is being built by Suparco (Pakistan Space and Upper Atmosphere Research Commission) engineers and technicians with foreign (not specified) assistance. Suparco is the official space agency of Pakistan, managed by Dr. Salim Mehmud. Its main activities involve remote sensing and sounding rockets.

BADR-A is designed to collect data from remote platforms It is possible that the satellite will be launched by a Chinese Long Mach 2 vehicle as a piggyback payload with a recoverable capsule in June.

Israel is promoting the role of space technology by encouraging the participation of industry in space projects and the start in Israel of original space ventures.

Dr. Dror Sadeh, director of the Israeli space research centre, stated recently that three spacecraft would be built by Israeli industry and one of them, for scientific research, would be launched by an indigenous launch vehicle. This vehicle could be based on the secret Jericho tactical missile

In addition, the private Israel Satellite Corporation plans to launch two Ku-band Amos communications satellites. The Amos spacecraft, developed by Israel Aircraft Industries (IAI) with some foreign assistance, would be of Europe's ECS-class.

Iran is continuing the development of its domestic satellite system, "Zohreh", consisting of three Ku-band spacecraft. This project is managed for TCI (Telecommunications Company of Iran) by SITAO (Satellite and International Affairs Office). A recent statement made by Dr. Mohamad Gharazi, Minister of Iranian PTT, indicated that the "Zohreh" project would cost around 600 million dollars, with the satellite(s) and ground segment being built in Iran.

INTERNATIONAL SPACE REPORT

Medical Laboratory for Mir Space Station

The Soviet Union is working on a complex medical laboratory for the Mir orbital space station in the early 1990s.

A report by Dr. O.G. Gazenko of the Institute of Biomedical Problems states that specially trained biologists and physicians will use Medilab for "extensive biomedical investigations in orbital flight".

Medilab will be brought to the orbital station using existing or advanced vehicles and used as part of the orbital complex. Two scientists – a biologist and a physician – will perform biomedical investigations, arranging biomedical investigations in a cyclic pattern of three months in duration. After each cycle, the specialists will be changed.

Biological objects and bio-samples will be returned to Earth for further analysis, although new physiological information obtained will undergo computer-aided processing onboard Medilab.

Biological objects to be used in the first cycle will be placed on Medilab before launch and during the unmanned portion of flight (prior to docking) data will be recorded and processed automatically.

Medilab, cylindrical in structure, will be separated into the following sections: lock and hygienic section joining the inner passage to the orbital complex; research section; experimental/surgical section; and a section for biological objects. All will be separated by solid partitions with doors leading to the neighbouring section.

The lock and hygienic section will be used by the scientists before and after experiments to wash themselves and change their clothes. The research section will be used for medical and physiological examination of crew members working on the orbital complex. This section will contain a wide variety of scientific equipment arranged in unified racks to allow easy access. The modular arrangement of the equipment will permit rapid replacement of units according to the experimental programme being undertaken.

Physiological data from various sensors and transducers will be collected by the commutation-distribution unit from where it will be passed over to the amplifying-recording units and computers.

The experimental/surgical section will be used to practice surgical techniques and carry out animal experiments. It will be equipped with a table-chamber and anesthesiology instruments as well as various other devices for physiological investigation work.

Theo Pirard

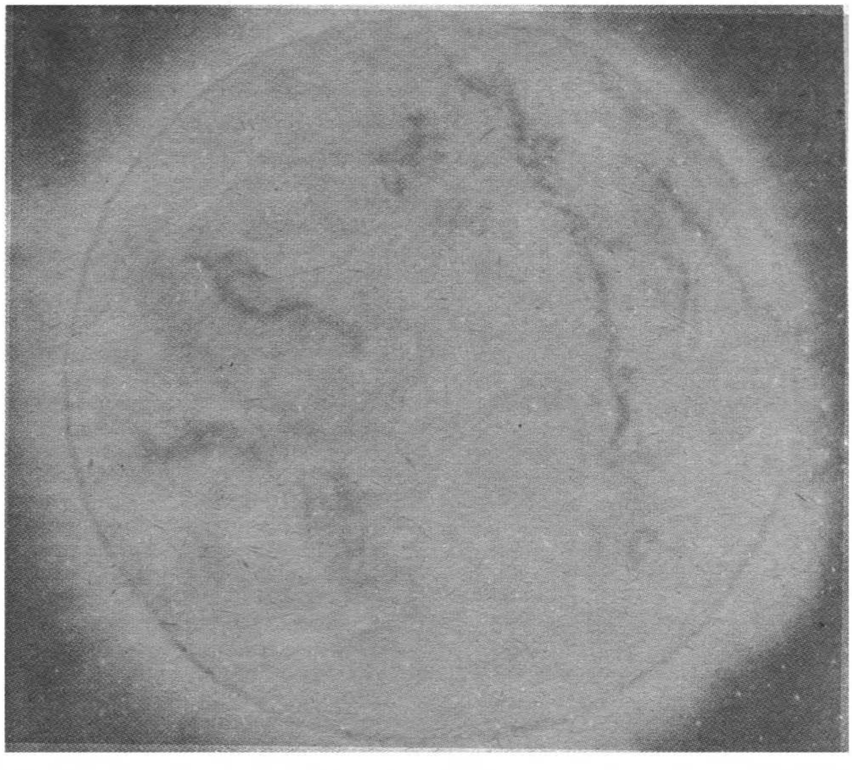
UK Not To Join Space Station

Kenneth Clarke, Minister for Trade and Industry, has confirmed that the UK is to pull out of ESA's manned space programme. Although the UK position was announced at ESA's Ministerial meeting in November 1987, the option for second thoughts remained open until the deadline of February 10. On that day, Mr. Clarke informed ESA that Britain would not be taking part in either Ariane 5 or the Columbus space station as presently proposed.

Mr. Clarke also confirmed the earlier announcement of no increased budget for the UK space programme, saying: "I am satisfied that the current level of government expenditure of £120 million a year is justified and I will continue to seek to use it in ways which are potentially beneficial to industry."

X-Ray Telescopes Capture Unique Solar Photos

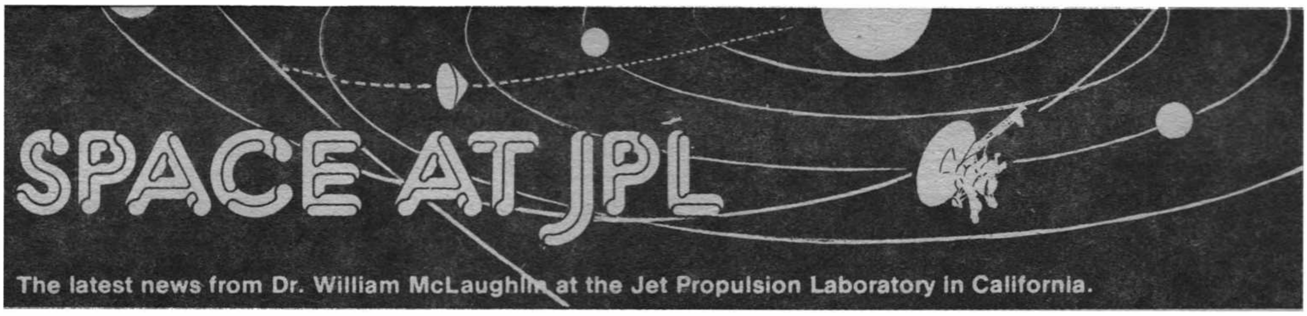
The first full-disk X-ray/XUV image of the Sun (right), which was captured by Cassegrain multilayer telescopes carried aboard a sounding rocket launched on October 23, 1987.



The high resolution X-ray image has unprecedently low X-ray scatter and features such as polar coronal plumes, dark filament channels and supergranulation cells (indicating turbulence) visible in the photograph may never have been seen before.

The images were produced on a new tabular-grain photographic emulsion developed by Eastman Kodak. The payload, launched aboard a Nike Black Brant VC, achieved a maximum altitude of 288.6 km and obtained images at several distinct wavelengths corresponding to solar plasma temperatures of 50,000 to eight million degrees Kelvin.

Principal investigators for the experiment were Prof. A.B.C. Walker (Stanford) and Richard B. Hoover (NASA) with Joakim Lindbolm (Stanford) and Troy Barbee (Lawrence Livermore) as co-investigators.



Neptune Science Planning

It is always a shock for a member of the Voyager flight team to be asked by an outsider if he or she is becoming bored during the long cruise from Uranus (1986) to Neptune (1989). The image is conjured up of languid days wherein the Voyager engineers faithfully hold in trust the spacecraft, waiting for the next encounter when they will leap to their television monitors to watch the pictures roll in. This view of mission operations is not uncommon, and, indeed, many spacecraft are relatively passive devices that require little sustenance. But the term "quiet cruise" always draws a chuckle from the Voyager team; cruise operations are tough and busy, and time is the driving parameter.

In previous columns, we have looked at some activities related to establishing the infrastructure for the Voyager/Neptune mission: mission planning (March 1987) and spacecraft improvements in flight (November 1987). This month we will continue the theme of cruise operations introduced in the November 1986 "Space at JPL" and see how the flight team is progressing with preparations for the August 1989 encounter of Voyager 2 with distant Neptune: an encounter where radio signals will take four hours to travel from spacecraft to Earth.

A useful way to understand all this activity is to approach it from the perspective of a "sequence load": a sequence of commands which is loaded into the spacecraft's onboard computers to guide the vehicle's actions for a period of time. When one load is used up, another must be ready to take over, giving the mechanics of load development a somewhat Sisyphean aura. The computers on the spacecraft are, of course, of 1970s vintage, when there were no flight-qualified microprocessors available. The space reserved for sequences is at most 2500 eighteen-bit words – minute compared to current memory capacities. Hence, great care must be exercised in packing the computers with an optimised set of sequenced commands.

There are three types of loads: (1) planetary encounter loads – ten of these will service the Neptune flyby by Voyager 2 during the period from June 5 through October 2, 1989, (2) cruise loads, that for Voyager 2 span the period from after the end of the Voyager/Uranus encounter (February 25, 1986) to June 5, 1989; Voyager 1 is always in cruise status, and (3) various contingency loads, which would be invoked only for certain anomalous situations.

Each type of load has scientific and engineering content, and we will focus on the planning for the former. Voyager's Science Investigations Support (SIS) team is headed by Peter Doms and is responsible for carrying out the bulk of science planning for the project.

Doms identified three primary drivers on the amount of work his team must handle:

1. The number of loads being developed at one time (in January of this year the number was seven: three encounter loads, three cruise loads, and one contingency load – all in various states of development. The number has gone as high as eleven loads at one time).
2. The planetary encounter trajectory that has been selected; the close overflight at Neptune's north pole and subsequent planetary and satellite occultations pose intricate coordination problems (see the March 1987 issue).

Cruise operations are tough and busy, and time is the driving parameter.

3. New capabilities in flight and ground software that must be designed, implemented and tested, plus maintenance of older systems (with regard to the latter, Steve Schlaifer of JPL has phrased it in memorable fashion, "code rots").

A fourth factor that intrudes upon occasion is the occurrence of a spacecraft anomaly, where intense involvement of the flight team is essential until resolution is achieved.

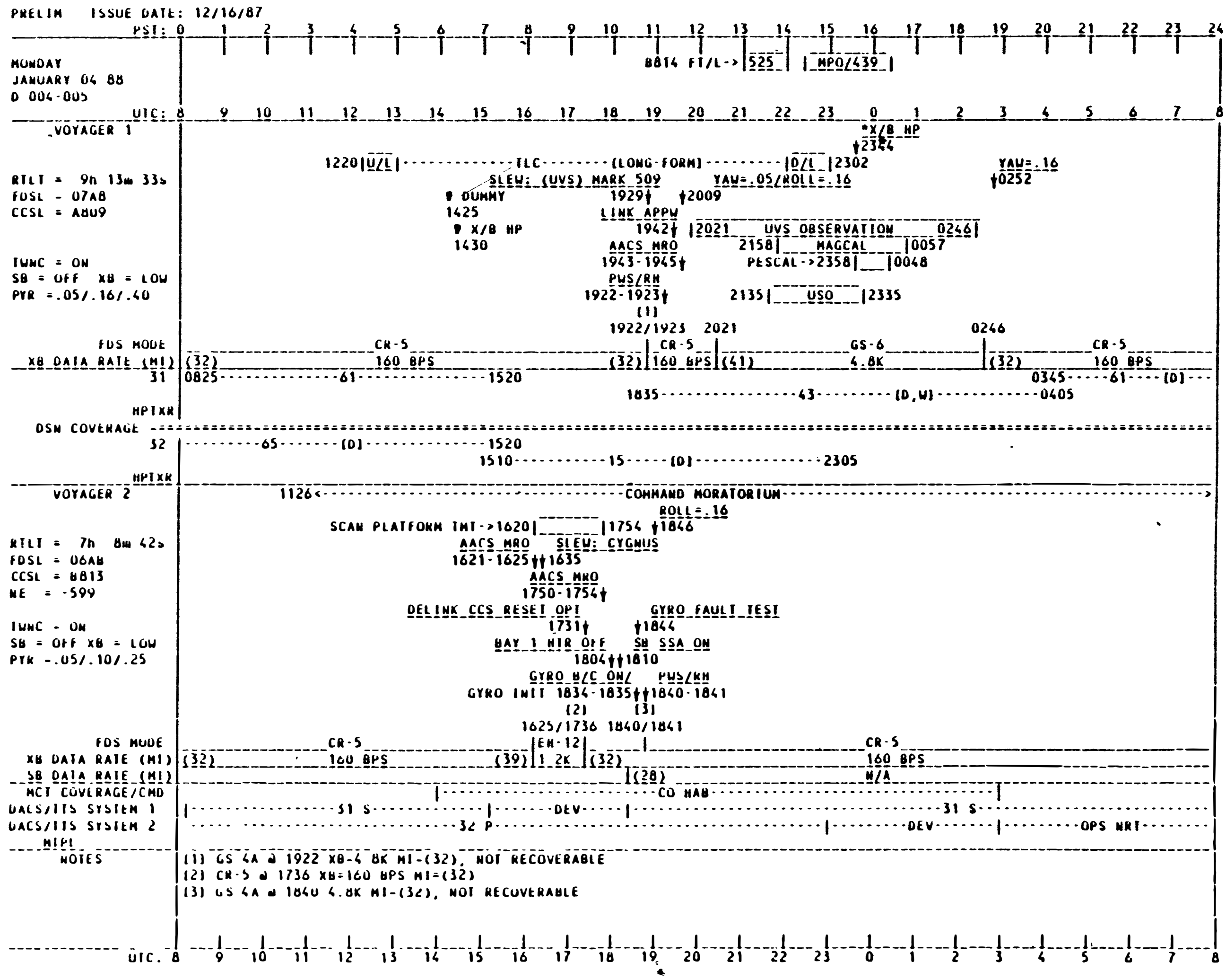
The SIS team engages in extensive coordination activities. For example, Doms estimates that he supports nine hours of regular meetings per week, plus another three or four hours of other meetings, on average. Many other SIS team members are similarly committed to rigorous meeting schedules. The frequency of meetings is indicative of the volume of work and information flow. We will review the nature of this work as it relates to the building of encounter loads.

The source of the scientific objectives is the set of principal investigators and their colleagues for Voyager's eleven scientific experiments. Early in a planetary-encounter cycle they meet in a series of workshops and working groups to lay out their fundamental goals and priorities (see the paper by Miner, Stembridge and Doms in the October 1985 ***JBIS***).

Following this overview, each load, in its turn, enters a scoping phase of about 10 weeks' duration. Science content versus availability of resources and engineering constraints becomes better understood, and basic parameters, such as the time boundaries of the load, may be adjusted. Many goals and priorities are renegotiated with the principal investigators as it becomes apparent that not all desired experiments can be accommodated.

The most intense involvement of the SIS team in encounter-load development takes place in the 16 to 20 weeks spent in putting together the integrated timeline for the load. This phase integrates scientific and engineering activities for the spacecraft into a conflict-free whole, to about a one-minute level of accuracy of placement. For example, the integration insures that at any one time only a single instrument's data need be tape recorded onboard in the high-rate mode, or that one experiment does not require the spacecraft to rotate while another requires stabilisation. What has been produced is a workable plan which incorporates the highest-priority science along with necessary engineering support. One might liken the integrated timeline to the first draft of a book. In pursuit of this metaphor, the workshops and working groups would produce the foreword to the book, and the table of contents would come from the scoping phase.

After the integrated timeline has been produced, about 20 weeks are invested in the advanced-planning phase of load development; the adjective "advanced" looks forward to the next stage of load construction. Another project element, the Sequence team, assumes primary responsibility for this phase, but the SIS team involvement in the load has by no means ceased. The programming of a Voyager load is a highly automated activity, relying heavily on the assis-



"A day in the life of Voyagers 1 and 2" is illustrated by the activities of these two spacecraft on January 4, 1988, as Voyager 2 cruises toward its August 1989 encounter with Neptune. For example, the ultraviolet spectrometer (UVS) of Voyager 1 (top half of figure) is used for an astronomical observation, and the magnetometer is calibrated (MAGCAL). Coverage from Deep Space Stations in Spain (61) and Australia (43) is provided. Note the long round-trip light time (RTLT) of over nine hours for Voyager 1. Voyager 2 activities (bottom half) include the read-out of the memory of an onboard computer (AACS MRO) and the switching on of the S-band solid-state amplifier (SB SSA ON) Due to a degraded (since 1978) radio receiver, there are predictable periods when commands cannot be reliably received by Voyager 2 (COMMAND MORATORIUM) Station coverage is provided by antennas in Spain (65) and California (15) *NASA/JPL*

tance of ground computers to do the actual coding. However, each stage in this process yields large amounts of computer output to be reviewed by the SIS team (and other project elements) to insure compliance with intent and to resolve problems. For example, it may be discovered that pointing favourable for one experiment may be hazardous for another, or that the spacecraft would react differently to a string of commands than originally expected. Upon completion of advanced planning, the load is "put on the shelf" and, in principle, is ready for transmission to the spacecraft for execution.

Finally, an update phase covers about the last 12 weeks before uplink of the load. Here, new science objectives based upon recent observations may be incorporated as well as the latest knowledge concerning the trajectory of the spacecraft and the calibration of its instruments and engineering subsystems. It is likely, for example, that images taken on approach to Neptune will suggest some modifications to the final camera-exposure strategy.

Cruise-load development is a somewhat similar process but begins with the advanced planning phase and restricts updates, on the whole, to incorporation of late trajectory knowledge. One cruise load currently under development for Voyager 2 will be dedicated to testing many of the new capabilities being built into flight software, including a new range of camera-control options and innovative tape-recording techniques for the Plasma Wave Subsystem.

Hard work, high morale and the promise of a new world go hand in hand.

The early months of 1988 began with a meeting of the Science Steering Group to review the results of the scoping phase for the two critical near-encounter loads. Another discussion related to near encounter concerned deliberations as to whether the spacecraft's cameras and other remote-sensing instruments should be turned protectively away from the direction of possible incoming particles during the time of crossing Neptune's equatorial plane (to avoid potential abrasion of the optics from small ring particles, should any exist). For a change of pace, the SIS had to leap ahead in mission time to participate in planning the content of some onboard flight software which will be necessary to load into the spacecraft after its encounter with Neptune. This software will control the intruments and process and package their data for transmission to Earth well into the first decade of the next century. Support is also being given to testing new software models of Neptune's hypothesized ring arcs.

Looking further downstream, the team will soon assist in testing to insure that the switchover by the project from a Univac 1100/81 to a Univac 1100/91 computer, scheduled for June 1, takes place without incident.

And, as always, the drumbeat of multiple-load development goes on.

The mosaic of activities that has been sketched here, for one Voyager team, is replicated in fervor throughout the project. Hard work, high morale, and the promise of a new world go hand in hand.

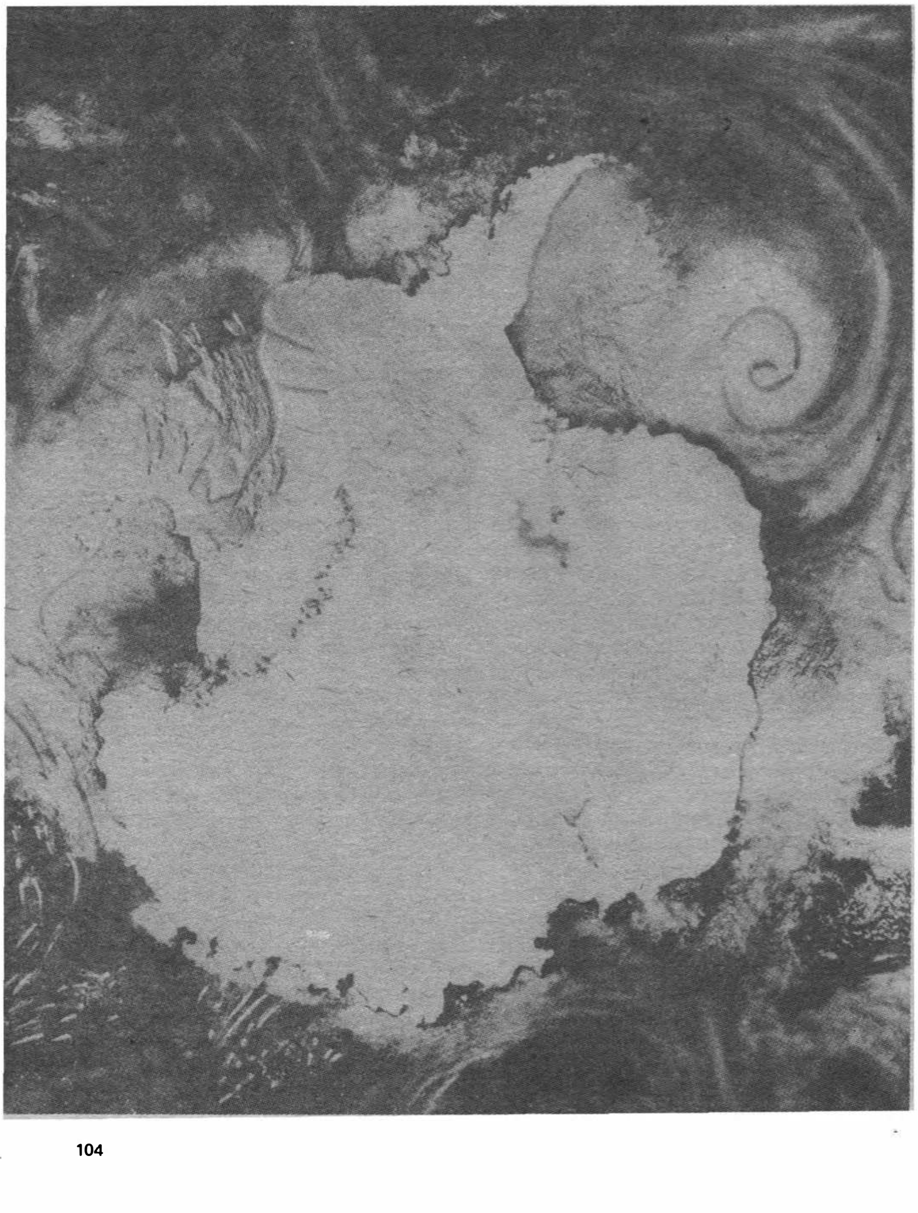
Ozone Chemistry

Since the late 1970s the stratospheric ozone layer over Antarctica has become depleted in the spring – yielding an "ozone hole" – while recovering during the subsequent portion of the year. Due to the crucial importance of stratospheric ozone as a shield against the biologically harmful effects of solar ultraviolet rays, this phenomenon has attracted considerable public attention and scientific research as to its cause. In 1974, prior to observational evidence of ozone depletion, Drs. Mario J. Molina and F. Sherwood Rowland of the University of California at Irvine suggested that man-made chlorofluorocarbons (CFCs) could pose a chemical threat to atmospheric ozone.

Molina, who has been a research chemist at JPL for the past five years, and his colleagues are currently investigating chemical mechanisms that could account for ozone depletion as a consequence of CFC compounds released in to the atmosphere. This laboratory work complements field studies conducted from the ground, airplane and Earth orbit; see the September 1987 and December 1987 editions of 'Space at JPL' for a survey of the results obtained by Dr. Crofton B. Farmer and his colleagues (also, the January 1988 issue of *Scientific American* contains a good review of ozone-depletion research).

Although it is well known that an ozone molecule (consisting of three oxygen atoms) is destroyed by colliding with a chlorine atom, producing molecules of oxygen and chlorine monoxide, several conditions must be met in order that this destructive meeting can occur. One of the principal elements in a CFC scenario for ozone depletion is the presence of clouds in the stratosphere over Antarctica. As will be seen, these clouds serve as a chemical workplace for the production of chlorine gas which, when split into chlorine atoms by the action of sunlight (a molecule of chlorine gas consists of two atoms of chlorine), supplies the agency for the destruction of ozone.

The Antarctic continent: compiled from five images collected between November 4 and 25, 1986 by the Defense Meteorological Satellite Program's Satellite F-7. Ozone depletion over Antarctica has been a concern in recent years. *USAF/NOAA*

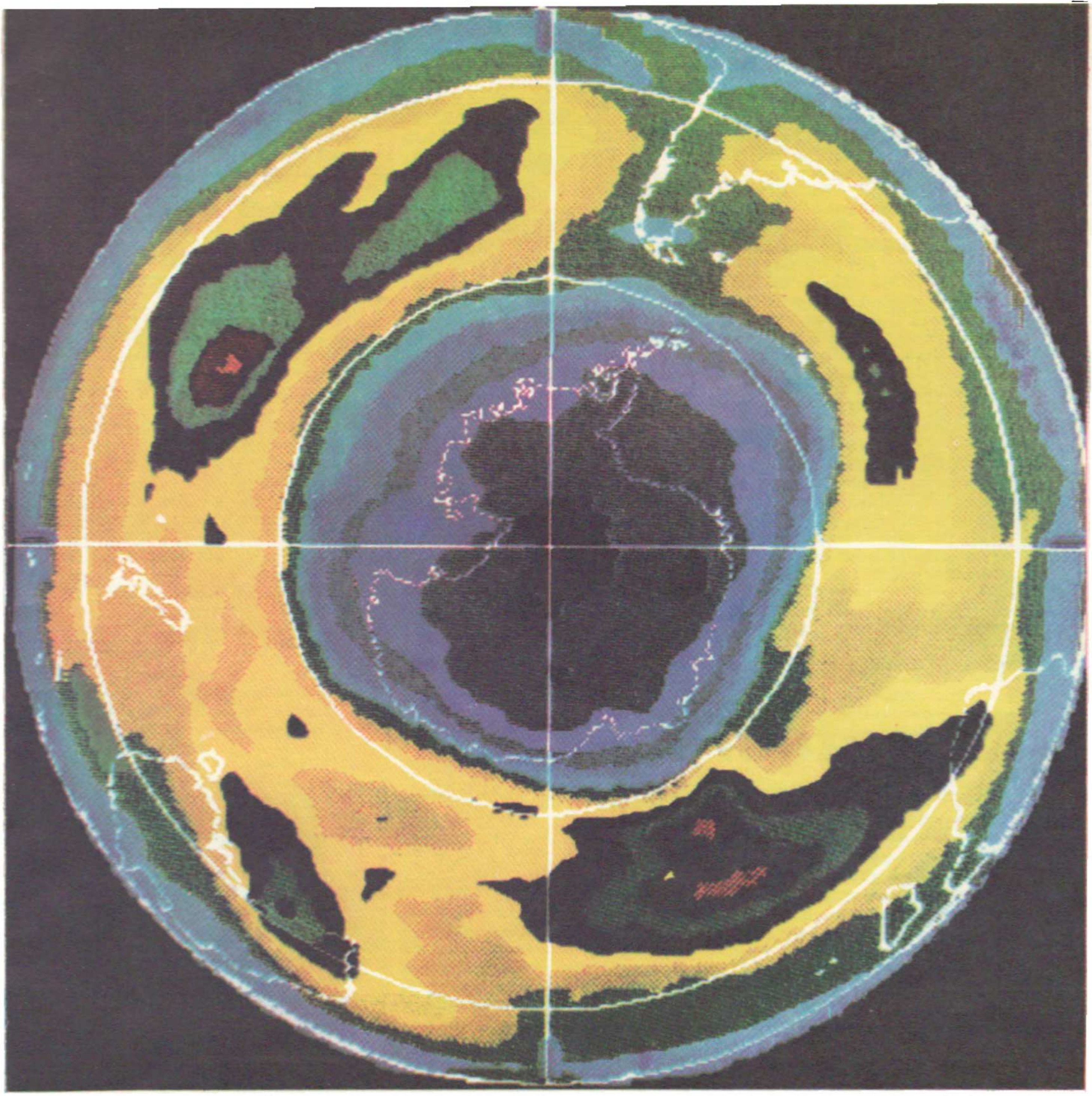


Before examining the chemical logic which Molina and his group have deduced, let us trace the origin of polar stratospheric clouds; most "weather", including clouds, is confined to the tropospheric layer, below the stratosphere. Typically, the troposphere extends vertically from the surface of the Earth to about 11 kilometres, where the stratosphere begins, and continues up to approximately 50 kilometres, but the dimensions of both domains vary greatly over time and location on Earth.

The stratosphere, unlike the troposphere, is dry and contains relatively small amounts of the water which is necessary for the formation of clouds. Much of the tropospheric air that enters the stratosphere does so over the tropic regions of Earth and is rich in methane ("swamp gas") derived from biological processes. Activities of tropical termites and gases expelled from the mouths of cows are two sources of such methane. The natural oxidation of methane in the stratosphere results in the production of water and carbon dioxide, and about one half of all stratospheric water comes from this source. Since the usual stratospheric circulation proceeds from the equator to the poles, the stratospheric air over the poles is wetter – yielding more clouds – due to the continuing oxidation of methane during travel.

Air that does arrive over Antarctica tends to become isolated there because of the vortex which develops over that continent: a consequence of the physics associated with the large land mass of Antarctica, a geographic feature not shared with the Arctic. Thus, the trapped stratospheric air, laced with water from methane oxidation, is subjected to the cold chill of the Antarctic, and the conditions of wet and cold air are ideal for the production of polar stratospheric clouds.

Within this physical setting, Molina sought the source of enough chlorine atoms which could account for ozone depletion. Man-made CFC compounds contain, as the name implies, chlorine, and dissociation of these compounds in the stratosphere does yield chlorine atoms and the consequent destruction of ozone. However, this mechanism alone would not suffice to explain the



Ozone depletion over Antarctica is shown in this satellite map as the darker regions in the centre of the figure The data were gathered September 27, 1987 by the Total Ozone Mapping Spectrometer onboard the Nimbus 7 satellite *NASA*

extent of the depletion of ozone observed in the Antarctic.

One of the secondary products of dissociation of a CFC is hydrogen chloride (not in itself a threat to ozone). Now the link to stratospheric clouds: Molina showed that airborne hydrogen chloride dissolves rapidly into ice, such as would be contained as small particles in the cold stratospheric clouds. As he says, "the ice clouds scavenge the hydrogen chloride".

With a second piece of insight, Molina and his team brought a large portion of the puzzle into focus. They showed that another gaseous constituent of the Antarctic stratosphere, chlorine nitrate, in itself (like the hydrogen chloride) not a chemical threat to ozone molecules, would efficiently combine with hydrogen chloride in ice to produce abundant supplies of chlorine gas. It was then a simple recognition by the chemists that the newly arrived springtime Sun in the Antarctic would split many of the chlorine gas molecules into the deadly (for ozone) chlorine atoms.

Both the rapid solubility of hydrogen chloride in ice and the rapid rate of the chlorine-nitrate and hydrogen-chloride chemical reaction were demonstrated in Molina's laboratory at JPL and, in fact, represent the centrepiece of his team's contribution to the understanding of stratospheric chemistry. Curiously, the chemistry of ice had been a relatively unexplored subject. For a technical report see the paper by Molina and his colleagues in the November 27, 1987 issue of the journal *Science*, as well as a paper by

Dr. Margaret A. Tolbert and her colleagues from SRI International.

Another loop in the chemical logic of the polar stratosphere concerns the manner of production of chlorine nitrate, which, as seen above, is a key ingredient in the process for generating active (atomic) chlorine in stratospheric clouds. This chlorine nitrate arises from the combination of naturally occurring nitrogen dioxide with one of the breakdown products (chlorine monoxide: through oxidation during the trip from mid-latitudes to poles) of CFCs. Not only does the participation of the nitrogen dioxide produce the required chlorine nitrate, but its removal from the atmosphere permits the active chlorine to attack ozone molecules without interference. Interference would have come from large amounts of free, gaseous nitrogen dioxide, which would neutralise active chlorine.

Thus, one begins to see the insidious attraction of the proposal of chlorine nitrate operating on a stratospheric ice bed, with hydrogen chloride, to produce ozone-destroying active chlorine; the proposal not only shows how the active chlorine arises, it also includes a mechanism for eliminating one of the chlorine's natural enemies (nitrogen dioxide) and ties it up harmlessly in the ice as a produce (nitric acid) of the reaction.

Although each step in the above presentation is relatively simple to grasp, the argument has several steps, and it will be useful to summarise the proposed chain in a simplified fashion.

1. Man-made chlorofluorocarbons (CFCs) migrate into the stratosphere and drift toward the poles along with the natural circulation of the stratosphere.
2. Methane from natural biological activity, particularly in the tropics undergoes a similar transport process.
3. During their periods of transport, the CFCs are oxidised into chlorine compounds (especially hydrogen chloride and chlorine monoxide) and the methane into water.
4. Chlorine monoxide (see 3.) chemically combines in the stratosphere with naturally occurring nitrogen dioxide and yields chlorine nitrate.
5. The water from the methane oxidation is an important (50 per cent) contributor to the formation of polar stratospheric clouds over the cold Antarctic continent.
6. Stratospheric hydrogen chloride (also mostly derived from CFCs) dissolves into the ice particles of the polar clouds.
7. The reaction of chlorine nitrate with hydrogen chloride in the ice of the clouds (see 6.) is an effective producer of gaseous chlorine.
8. The recently arrived Sun of the Antarctic spring breaks down (photolyzes) chlorine molecules into chlorine atoms.
9. These active chlorine atoms convert ozone into oxygen, creating the observed ozone hole.
10. Naturally occurring nitrogen dioxide, which would be expected to neutralise chlorine atoms, has been greatly reduced in quantity by its role in the production of chlorine nitrate.

The laboratory work and proposal of reaction mechanisms proceeds hand-in-hand with field work. For example, measurements made in Antarctica in 1986 and 1987 show low levels of nitrogen dioxide and high levels of chlorine monoxide in the gas phase and the presence of nitric acid in the ice particles, consistent with laboratory predictions.

A lot more work remains to be done observationally, experimentally and theoretically before full understanding of mechanisms of ozone depletion is obtained. It is, of course, very important to be able to model the life cycle of ozone over mid-latitudes, where the bulk of the Earth's population resides. Regardless of final conclusions, enough concern has been raised to initiate the control of CFC releases into the atmosphere. Laws (as early as 1978) and international accords are paving the way toward reduction in the use of these potentially damaging substances.

Nanotechnology

Is it possible to build a miniature machine whose parts measure only a few atoms in size? Of course, nature has been building molecular-sized machines for quite some time now, but computer scientist K. Eric Drexler of the MIT Artificial Intelligence Laboratory believes that in the next few decades human engineers can extend their competence to domains where the nanometer (one thousand millionth of a meter) is the standard of reference: nanotechnology. He does not foresee just some form of clever chemistry but rather a discipline that employs molecular-sized gears, bearings, rods and even builds nanocomputers. For example, Drexler postulates the future existence of nanosubmarines coursing through the human bloodstream selectively scouring its pipings of fatty deposits, viruses and bacteria.

Drexler has given considerable thought to his blueprints and expressed their content in a recent book (*Engines of Creation*, Anchor Press, 1987) and, among other places, in the *Proceedings* of the US National Academy of Sciences (vol. 78, pp. 5275-5278, September 1981). The computer aspect of his work has been emphasised in "Computer Recreations" in the January 1988 *Scientific American*.

The concept of nanotechnology has broad scope and potentional, but is it valid – will it come to pass? Drexler's strategy of affirmation rests on three points: (1) cataloging a set of possibilities with strong appeal, thus motivating their realisation, (2) pointing out that quite similar activities are regularly carried out by nature – as mathematicians would say, establishing an existence theorem, and (3) dealing one-by-one with selective objections, e.g., quantum uncertainty effects would not be significant in structures as large as molecular machines. The idea of nanotechnology certainly has a respectable pedigree, with Nobel-laureate Richard Feynman of Caltech producing some early speculations in this arena in 1959.

The pictures painted in *Engines of Creation* are compelling. Witness the description of the last stages of construction of a full-sized rocket engine by a legion of molecular machines toiling in a soupy vat of raw materials. "As the fluid clears, the shape of the rocket engine grows visible ... the flowing fluid brings fresh fuel and dissolved raw materials for construction; as it flows out it carries off waste heat. The communications network spreads instructions to each assembler ... [the finished engine] is a seamless thing, gemlike ... Compared to a modern metal engine, this advanced engine has over 90 percent less mass ... For all its excellence, this engine is fundamentally quite conventional. It has merely replaced dense metal with carefully tailored structures of light, tightly bonded atoms. The final product contains no nanomachinery."

The visions of Drexler are relevant to space research in more than production of tough, reliable hardware, important as that application may be. Specifically, they show promise in developing transportation systems for interstellar flight and may shed some light on a paradox in the search for extraterrestrial intelligence. Before pursuing these two subjects, let us understand the essentials of Drexler's thesis.

Three fundamental types of nanomachinery are envisioned: nanocomputer, assembler, and disassembler.

Drexler opts for a mechanical computer rather than an electronic one. The logic of this nanodevice, packing 1000 million bytes of information into a space scarcely the size of a bacterium, would be carried out by a series of interlaced rods positioned in a three-dimensional matrix, much as computer pioneer Charles Babbage (1792-1871) foresaw in the mid-nineteenth century. Mechanical action for molecular machines would be slower than electronic action, but these small computers would still be extremely fast. More advanced nanocomputers might employ electronic techniques, gaining even more speed.

Assemblers would be guided by nanocomputers in the task of bonding atoms together in chosen patterns, e.g., a rocket engine. Assemblers would be constrained in putting together structures consistent with atomic-bonding patterns, but they could easily pursue what are now, chemically, seen as slow reactions. Already, using macrosized devices we have been able to approach and interrogate single atoms with the Scanning Tunnelling Microscope; see "Space at JPL" in the August 1987 issue.

Disassemblers reverse the assembly process and take apart a structure atom-by-atom, layer-by-layer. They are to be used as analytical devices by recording the act of disassembly, thereby gaining exact information as to the construction of the disassembled object. This information is stored in a computer and can be used to drive assemblers to create perfect copies of the original object.

To accompany his nanohardware, Drexler invokes software based upon artificial intelligence (AI). Although it is not an unreasonable assumption to believe that progress in the next few decades will produce effective AI tools, there is an added impetus to be gained through nanotechnology. Drexler points out that the neural patterns of the human brain can be utilised, once having been recorded by the act of disassembly, even if the "inner secret" of their functions is not understood. In fact, Drexler anticipates mechanical improvements in what would otherwise be a copy of the human brain, by assemblers, so that the resultant product would occupy only one cubic centimeter (a thousand-fold compression from our brain) and operate one million times faster, albeit with some cooling problems if one were to utilise the higher operating speeds. These "larger" computers would act as senior advisors to the nanocomputers, in a hierarchical information network.

Interstellar flight would benefit in two areas from nanotechnology. If, for example, one considers sail ships driven by the light pressure from banks of solar-system-based lasers, then assemblers would produce ample quantities of high-quality mission equipment: low-mass sails, lenses, lasers, etc. This function is analogous to the production of rocket engines. In addition, the structure of the ship could be modified in flight to perform more efficiently during successive mission phases – cannibalising old structures to produce new ones.

The second benefit to interstellar flight would be even more dramatic. The initial payload delivered from Earth to the target stellar system would only need to be of minimal mass, easing propulsive requirements for the trip across the interstellar gulf. Once at the target system, the vehicle would deposit, via an atmospheric probe, an assembler system (with guiding nanocomputers) on a planetary surface and proceed to build components for the next stage of exploration. The planet would be identified by a large space-based telescope and selected for suitable raw materials: carbon, hydrogen, nitrogen, oxygen. One of Drexler's toughest materials is carbyne, assembled from a chain of carbon atoms.

A first task would be to build a large antenna to enable efficient communications with Earth. Later, a bank of lasers could be built to decelerate other incoming sail ships. The on-site manufacturing scheme is a grand version of earlier and simpler proposals such as *in situ* propellant production on Mars (see the September-October 1983 edition of this column).

The link of Drexler's work to the subject of extraterrestrial intelligence comes via the so-called Fermi-Hart paradox. A remark of physicist Enrico Fermi (1901-1954) to the effect that if extraterrestrials exist we ought to have encountered them – where are they? – was revived with great effect by Michael Hart in 1975. The "Great Silence" or "Where are they?" debate has been pursued with vigour in the last decade with two rival schools emerging: (1) extraterrestrials exist but have not colonised the Solar System due to difficulties in interstellar travel or from their imposition of a quarantine on the Solar System, and (2) extraterrestrials do not exist (Hart's answer).

Your correspondent has espoused the "epistemological solution" that claims the times for interstellar migration, probably being at least a few hundred thousand years according to most analysts, are so long that directed evolution would have carried potential colonisers clear out of our field of recognition, before they could ever arrive here. Briefly stated, evolution rates exceed interstellar migration rates (see my commentary in the May 1986 edition of this column).

In other words, the time putatively utilised by an extraterrestrial spacefarer to migrate from its home planet to the Solar System would be a time for evolutionary growth. This growth would be laid on top of an original development state for the extraterrestrial who was registered at about our present level of "beginning spacefarer".

Most biological systems are hierarchically constructed, because improvement on an existing design is easier and, hence, more probable than starting all over again. Thus, an extraterrestrial tens to hundreds of thousands of years beyond our state of development would be one or more steps up the hierarchical ladder from us. Drexler's scenario provides a graphic illustration of how rapid and epistemologically divisive such a step, even in the next hundred years, could be.

Mutual recognition between co-evolvers such as humans, bears and snakes is well established through necessity of survival (but weakly related evolvers such as ants may have trouble recognising us). Mutual recognition between hierarchical levels is much more difficult than between co-evolvers. Consider how long it took our conscious selves to recognise adequately our subconscious components (Freud, *circa* 1900), and how difficult the recognition in the other direction must must be! Inter-hierarchical recognition is made difficult not only by differences in capability but also by the greater scope that a system enjoys compared to any of its subsystems.

A reasonable (assuming nanotechnological premises) guess as to the form of an advanced extraterrestrial, one or two steps further up the hierarchical ladder, would place it beyond molecular machinery and into the database realm revealed by disassemblers and managed by AI capabilities. Why reassemble into wet and quivery protoplasm, or similar forms, the information obtained by disassembly of a biological brain? Information management would be so much simpler. Extraterrestrials would, in this view, merge into being more creatures of the electromagnetic spectrum than otherwise: "such stuff as dreams are made on".

Thus, we can glimpse in Drexler's work the possibility of a rapid and drastic change from a brain-based level to (for lack of a better term) a mathematically-based level. The step would be at least as decisive as the earlier evolution from genetic dominance to brain dominance of behaviour.

Are there physical alternatives to residence in planetary biomes? The vacuum as revealed by modern physics is anything but empty. Consider that our complex universe emerged from it in the Big Bang. Might we ultimately return to our origins as creatures of the vacuum?

Note that the epistemological solution to the observed absence of extraterrestrials on Earth is neutral with regard to the density of extraterrestrials in the galaxy. It simply says that there is an alternative answer to "Where are they? than, "They don't exist".

But enough of this heartless viewpoint. We applaud Eric Drexler's imagination and well-conceived designs and look forward to future developments in nanotechnology.

SOVIET SCENE

Mir Communications in 1987

by John Branegan

Up to 1986, the communications from Soviet space stations were relatively unsophisticated and static. That has all changed. Last year has seen considerable expansion and elaboration on existing channels, and the establishment of several new channels. There have been problems, with geosat relays, power supplies, incompatible equipment, natural interference, and cosmonaut health, but the Soviets have not allowed this to upset the forward progress. With the result that 1987 was a year of remarkable achievements.

Introduction

With the Soviet presence in space now continuous, all the year round, activity at the space station has been at a very high level. As the paragraphs which follow explain, this tremendous increase in the quality and content of the cosmonauts' workload has been clearly evident on their communications links, allowing UK listeners to closely follow the day to day progress of events.

Communications Ships – Comships

That Mir and its proposed Kvant science module would require enhanced communications links was clear before February 1987 but instead of these links being made available via the anticipated use of a geostationary relay satellite, the first month of Mir occupation in 1987 started with the reinstatement of an older type of communications link.

Shortly after Romanenko and Leveikin joined Mir, in February 1987, a typical day's communications pattern heard in UK had the following timings: 1223, 1359, 1535, 1709 and 1843 UTC/GMT.

Cosmonaut Tune-ins – What you can hear

These communications events had separating intervals of: 96, 96, 94, and 94 minutes, forming a typical pattern of five consecutive orbits where Mir talked to stations in the USSR.

Some days later however the pattern of timings was: 1221, 1355, 1531, 1659 and 1833 UTC/GMT. At first sight this may appear nearly the same as its predecessor, but when the intervals are calculated, it produces: 94, 96, 88 and 94 minutes.

The marked change in the size of the third interval indicates that Mir cosmonauts were not talking to a station in the Soviet Union, and a check of where they were six minutes early on the fourth orbit showed them coming across the North Atlantic Ocean having just overflown the eastern seaboard of Canada. When this sequence was repeated over several days it was possible to use simple triangulation to show that they must have been talking to someone located just off the east coast of Nova Scotia, where shallow water over sand banks near Sable Island allowed mooring of a ship in international waters. American Mir watchers soon confirmed the presence of the Russian Comship 'Yuri Gagarin' at this location. Figure 1 shows the location of Sable Island.

Identifying a Comship

The actual signal being heard in the UK was coming from Mir as it re-broadcast the Comship uplink. Listening to the Comship transmission in the background of the Mir signal two features identified it as a Comship. Firstly, there was a noisy low frequency rumbling sound superimposed on the Comship signal. This was the ventilation trunking in the Comship's Radio Room, resonating at harmonics of the fans' speed of rotation. Secondly, the Comships Radio Room was much more crowded than the typical "Cathedral-like" ground control station, and this too affected the noise background on the Mir signal, producing almost a "cocktail party" level of hustle, bustle and verbal graffiti. Stations in northern and western UK could

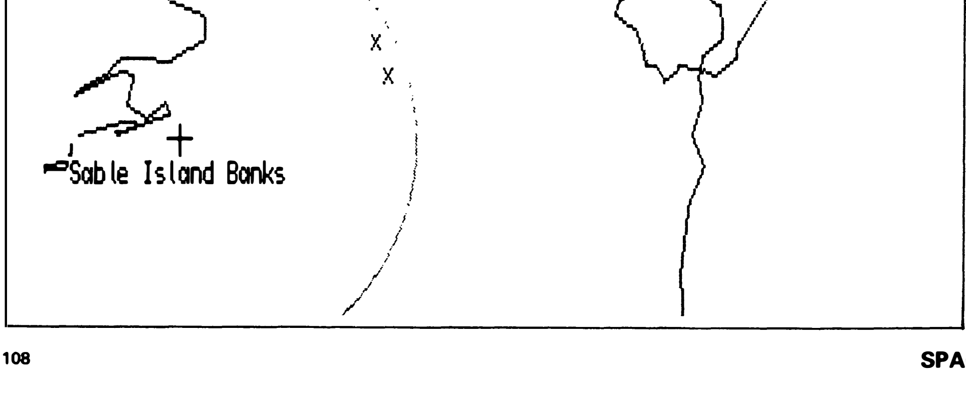


Fig. 1. When Mir is near the eastern edge of the inner circle (x), its downlink to the Sable Island Comship can be heard in northern and western UK.

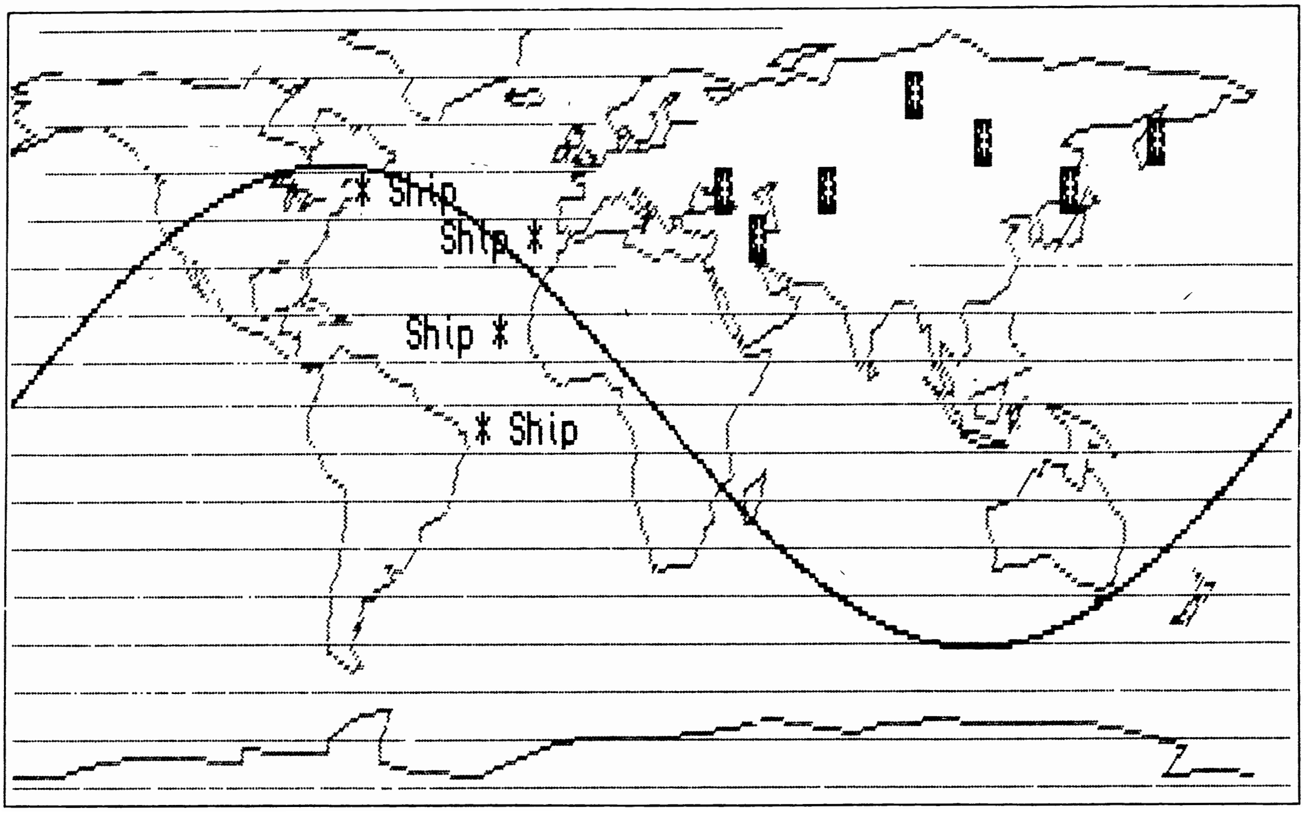


Fig. 2. Comship extension of Soviet VHF radio control network. A typical Mir space station track – ships may be located under the track at any of the four regular sites shown. Communications to northern pair are audible in the UK.

hear all this on 143.625 MHz FM as Mir talked to the Comship.

Why Comships? Why Sable Island?

Figure 2 shows a map of the world on which the locations of Soviet land based ground control stations are indicated by inverted asterisks. Please note the relatively small unlined area at the top right of this map which a Mir orbit must enter before the cosmonauts can use VHF to talk direct 'line of sight' to Soviet Ground Control.

As Figure 2 shows, a Mir orbit crossing this unlined portion of the map can be passed on from one ground station to the next one to its east, in succession across the USSR, west to east. However, the particular orbit track shown never comes in range of a single ground station. This track is in fact one of a sequence of four orbits which never come in range of the USSR.

Individual orbits which do cross the USSR do not all cross the whole country, some only cross the eastern or western edges, so these orbits only see the USSR for about eight minutes at a time, as compared with the roughly 24 minutes of communications time available for those orbits crossing the whole country.

Figure 3A shows the pattern of communication opportunities available to Soviet ground control. Only about 220 minutes a day are available for communication and this total is divided up into small discrete blocks. Even worse, there is a roughly six hour gap where no orbits come in range of the USSR.

Figure 3B shows how a ship moored off Sable Island slots neatly into this pattern, fulfilling two vital functions. Firstly, the dangerous communications gap is bridged and, secondly, the Sable Island Comship can debrief the cosmonauts immediately after they have flown over the United States. That this second point is important, is borne out by the kind of traffic passed to the Comship. The messages are of an unusual type, consisting of a list of numbers which appear to form an encoded situation report. It is significant, that these reports always follow overflights of USA, that they are not used in other circumstances, and that the numerical sequence often ends with the phrase "otherwise normal".

The reasons for choosing Sable Island are therefore strong ones. The reasons behind the choice of the other regular Comship locations shown on Figure 2, are believed to be quite different. Comships appear to be located at one or other of these sites when important landings are planned. The sites chosen can cover the vital requirements for communciation, just before and just after re-entry into the atmosphere prior to landing. Stations in northern and western UK can hear communications to the Sable Island, Straits of Gibraltar and Canary Island sites, but not the more southerly Brazilian site.

A Comship occupied the Sable Island station almost continuously until late summer of last year. Then after a break of several weeks a new Comship appeared on station south of Gibraltar, near Madeira. This new location allowed ground control to adjust Mir's pointing attitude just before its orbit took it south of the equator, where it could start viewing Super Nova 1987.

Comships cost more than £3 million per week to run and in the long term, as the next paragraphs explain, a geostationary relay satellite should prove a better option. Unfortunately, the Russians appear to have had no better luck in 1987, with their geosats, than the Americans have had with their equivalent TDRS Tracking Data Relay Satellites.

Geostationary Relay Satellites

In 1986, the Mir VHF downlink was frequently left "on", even when Mir was thousands of kilometres from Soviet ground control. This allowed the cosmonauts to be heard going about their work, whilst their discarded boom microphone headsets picked up and faithfully transmitted on the downlink, all the extraneous noises in

*In the October 1987 issue of ***Spaceflight*** *John Branegan* introduced the subject of 'Listening to the Cosmonauts' with an article which included details of the relatively simple and inexpensive equipment needed for monitoring orbital activity. Copies of this ***Spaceflight*** can be obtained by sending a cheque/postal order/international money order for £2.00 (inc postage) payable to the British Interplanetary Society at 27/29 South Lambeth Road, London SW8 1SZ, England

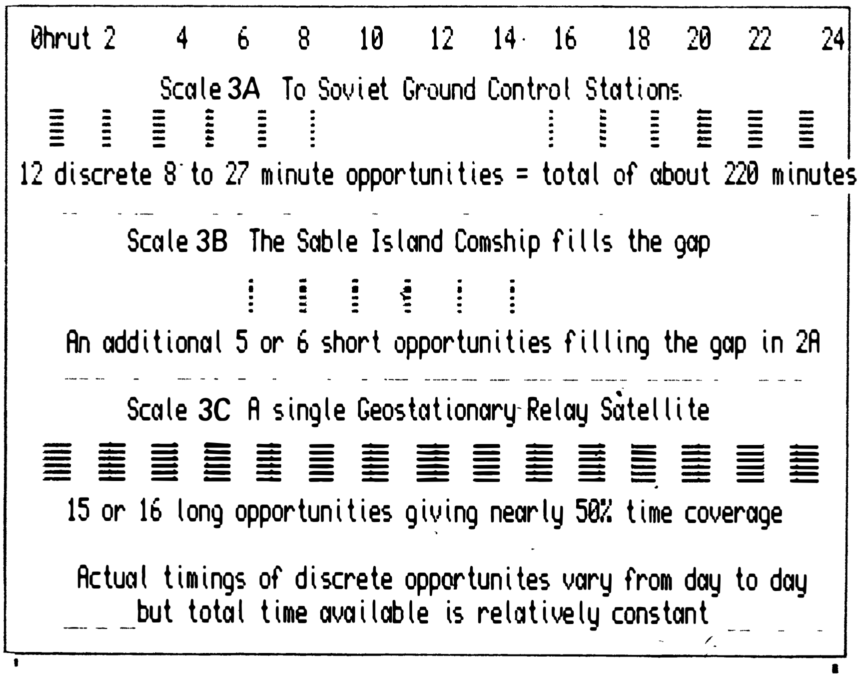


Fig 3 Typical daily pattern of Mir VHF communication opportunities.

the space station. Amongst these noises as Mir came into range of the UK was a regular pip tone time signal, and, as the station passed over UK and continued eastwards towards the Soviet Union, this pip tone at one second intervals was suddenly overlaid by a rapid six pip sequence. At this point the cosmonauts would down tools, don their headsets and start talking on the VHF downlink. Checks on many separate events pointed to a geostationary relay satellite as the source of these pip tone signals, warning the cosmonauts that they were in line of sight VHF range of a Soviet ground command station.

Figure 4 shows an overview of the ground-to-geostationary-to-Mir signal path. Figure 5 shows a map projection of the situation indicating how a roughly 40 minute part of every successive Mir orbit can be seen by the geosat relay. Figure 3C shows the very big improvement in useful communications time that the geosat relay provides.

In February 1987 Romanenko and Leveikin went up to Mir, but the re-broadcast of the geosat signals was missing from their regular VHF downlink communications. Indeed, aside from the odd relay of TV from Mir which used a different geosat, there was little sign of any geostationary voice or data supplement to Mir communications except for a period in late October 1987 when trials appeared to be taking place through a geosat link. These trials involved typical tests of what may have been Mir acquisition and lock-on to the geostationary beacon carrier, but no regular pattern of geosat communications followed.

Geostationary Relay Satellites

As mentioned earlier, the seven major Soviet ground control stations can only provide communications to and from Mir for about 220 minutes of a 1440 minute day. This is both unsafe and a serious impediment to a smooth work pattern.

Figure 3C shows how a single geosat relay stationed over the equator at 95 degrees East, can communicate with Mir for a 40 minute session every orbit and, perhaps even more important, it can use wideband microwave links capable of handling far more data than the very restricted direct VHF links.

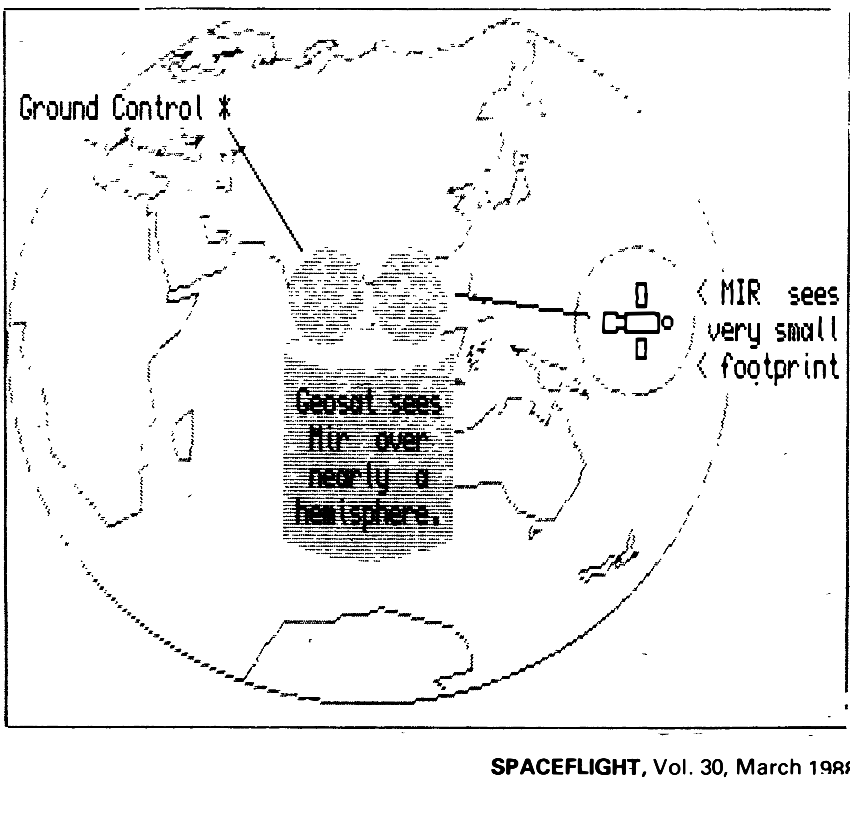
The failure of the vital geostationary relay, sometime between August 1986 and February 1987 must have imposed serious limits on the Mir operational envelope in 1987. Two important aspects of these communications limitations were very noticeable. Firstly, in regard to the operation of the Kvant science module and, secondly, in regard to Mir navigation.

Kvant – The First Science Module

The Mir space station is designed to form the nucleus of a group of modular units, which can be launched individually, then assembled and plugged together, once they are in space. Kvant was the first of these modules to become operational, and it was finally docked with Mir after some very exciting communications on April 12, 1987.

From then onwards the communications links began to give details of problems. The first difficulty emerged when it became clear that the existing Mir solar panels could not produce enough power for Kvant. The module uses six momentum wheels arranged as pairs with a pair spinning around each of the three axes of movement. These spinning wheels have to turn and stabilise Kvant and the attached Mir and Soyuz. This took more electric power than Mir had available, so the cosmonauts did two space walks and

Fig. 4. Geostationary relay between low altitude space station and Earth.



SOVIET SCENE

fitted a supplementary solar panel. Whilst waiting for this modification, the cosmonauts carried out experiments which did not use high power, but even here it was clear that space station vibration caused some problems, and some particularly noisy, vibrating machines were absent from the downlink background noise for long periods.

Once the three axis stabilisation was working the cosmonauts began looking at Super Nova 1987 in the Magellanic Cloud and by July it was obvious that some unexpected results had occurred. The availability of Kvant's West German/British/Dutch/Russian High Energy X-ray equipment and the appearance of the first naked eye Super Nova near our galaxy for 300 years was a marvellous piece of good fortune. Up to then, theoretical physicists had suggested that the Super Nova high energy X-rays might not be visible until it was about a year old, but by July 1987 Kvant was proving them wrong.

This led to an intense series of Kvant observations of the Super Nova in the second half of August. The associated transmissions appeared odd to UK listeners because the cosmonauts and ground control seemed to be preparing their observations as Mir departed southwest of the UK heading down towards the Equator. The problem was that the Super Nova is towards the South Pole of the heavens and best viewing would have been from Mir's furthest southern latitude, not the Equator. This was resolved however when it became clear that the observations had to be done as soon as Mir passed south of the Equator because at higher southern latitudes the X-ray telescopes were suffering from severe electron precipitation (noting that Mir flies in the ionosphere).

From then on the observation programme became so intense that ground control was often commanding the Mir Kvant complex to turn and point towards the Super Nova whilst the cosmonauts slept.

Then, by mid October, a change had to be made when the long stay Cosmonaut Yuri Romanenko became tired and had to do less work, although even at this stage there were problems when the X-ray telescopes were found to be suffering interference from some electrical/electronic source in Mir (users of computers alongside sensitive radio equipment will be familiar with this kind of problem).

Data Communications

Up to March 1987 the Mir VHF downlink had been used almost exclusively for voice communications, but even before Kvant was launched the Mir cosmonauts began sending data

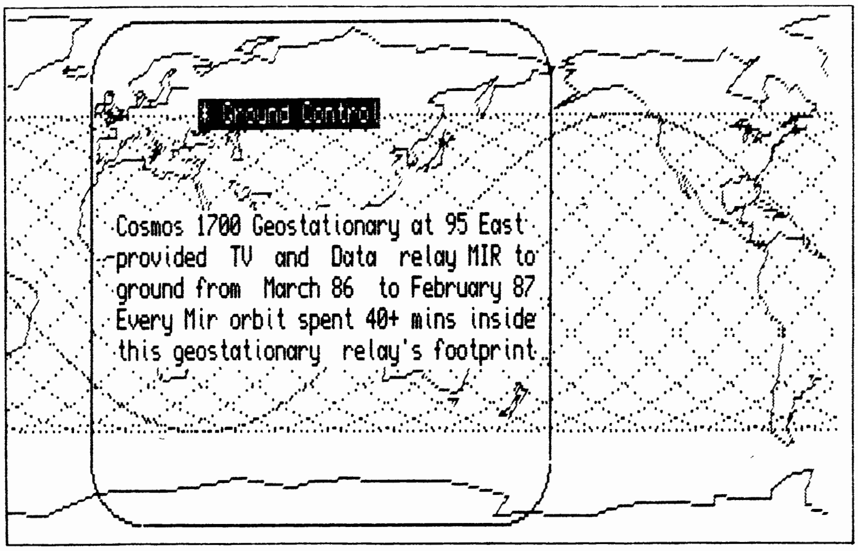


Fig. 5. Mir geostationary telemetry and communications links. Practical geosat cover is shown at Mir height, not at the Earth's surface.

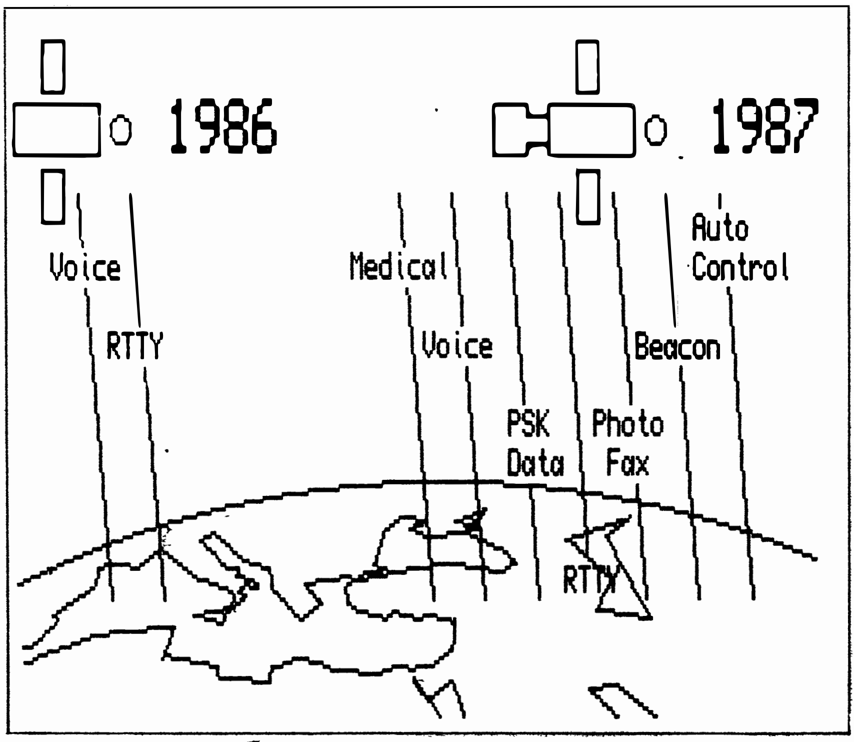
communication Phase Shift Keyed signals on the VHF downlink. That these were tests was evident from the format and Romanenko's verbal introduction of "lad na" (on tune) as he switched on the pre-recorded signal and shifted the downlink from voice to PSK. Later attempts when Kvant had arrived were far less numerous than expected but did read as genuine attempts to pass data.

As heard in UK these signals were of very poor quality, and on several days (especially on June 18, 1987) VHF propagation conditions down through the ionosphere were dreadful. Voice was badly distorted and the PSK signals suffered very badly when Sporadic E anomalous propagation was present. Since last July the cosmonauts have used PSK rarely, perhaps suggesting that the Soviets are giving up this aspect of Kvant data transfer until they have an operational geostationary relay.

New Mir and Soyuz Beacons

In September American listeners reported that Mir was sending FM telemetry late at night on a frequency of 166.140 MHz. The suggestion was made that this was a "Mir Night Watchman" automatically reporting the safety and security of Mir whilst the

Fig. 6. The changing scope of Mir up and downlink VHF communications modes.



SOVIET SCENE

Artist's impression of how the Mir space station could look in the early 1990s. Mir already has one module (Kvant) added to its original structure and a second is expected by the end of this year. The Soviets are also planning a special Medilab (see p.101). *T Pirard*

cosmonauts slept. There has been no European confirmation of this signal.

Shortly after the American report, Birger Lindholm in Finland reported that Mir was using a new beacon on 166.123 MHz. This signal was being heard regularly in UK as 1987 closed. Its main characteristics are: receivable on FM(N) or AM(N) as a rough buzz and on CW/SSB as a rough "auroral" hiss. No keying is discernable, but the carrier frequency may be swept at about 300 times/sec. It has been heard two or three times daily, both in daylight and at night, and it is switched 'on' by ground command as the space station approaches the USSR (ie, as it drops to the UK eastern horizon).

Soyuz TM-4 was heard on December 21, 1987 using a similar beacon on a frequency of 166.150 MHz.

The function of these beacons is at present uncertain, but one suggestion is that they resemble Round Trip Secondary Radars. Inputs to the signal in addition to range may be Mir attitude pointing data (Bahn numbers). UK listeners will find 166.125 MHz a very noisy frequency, regularly used by UK Public Service Repeaters, so the beacon just below it may not be easy to hear.

Mir Navigation

One of the problems of not having a geostationary relay, is that Mir's direct VHF downlink communications opportunities are of short duration and occur in an irregular sequence (as Figure 3A shows). The nuisance this creates is clearly evident on the downlink with cosmonauts often calling ground control when they are still 1000 km outside Soviet airspace. This was very obvious during 1987, with up to three minutes being wasted calling every minute or so, before finally getting a reply.

Soviet ground control cannot of course hear this problem, but it is an important one because it raises some interesting questions regarding what the cosmonauts are using for navigation if they are uncertain of their position to within 1000 km.

With 'head-up' displays and computer generated moving maps being standard features of western aerospace technology, it seems unlikely that the Mir cosmonauts are still using the analogue device, consisting of a Mercator map of the world between latitudes 65 N and 65 S covered by a transparent overlay on which is scribed the Salyut/Mir orbit. The method uses hand wheels below the display to allow the orbit transparency to be aligned with the map in order to match Salyut/Mir's Ascending Equatorial crossing longitude and could easily account for positional inaccuracies resulting in timing errors of a minute or two.

The fact that positional inaccuracies of this type still occur in Mir suggests that this track simulator may still be in use in 1987. Indeed, ***Spaceflight*** (August 1987, p.283) appears to have something very like it as item 20. So perhaps the Mir cosmonauts are not highly computerised and can be excused their timing lapses, although this begs an awful lot of questions as to how accurately they can locate and classify unfamiliar ground reconnaissance targets?

Next Month: *John Branegan* explains how you can make your own Mir predictions using a simple but effective tracking method.

Space Medicine

Two problems occurred in this field in 1987. The first involved Flight Engineer Laveikin, who was replaced in July because his heart beat was showing some irregularity. In fact, initial indications of this problem were broadcast in early May, when a curious pulsing facsimile type signal was transmitted on the downlink. Gradually, through May and June this signal featured more and more in the daily transmissions from Mir, such that by the end of June it was being heard three times on some days.

The signal was a puzzle. Sometimes at about 70 pulses per minute, but at other times speeding up to 110 pulses a minute, and it was not until the signal was heard by a medical practitioner, that the suggestion was made that it sounded like the record of a cosmonaut's heart beat. Slow when he was relaxed and fast when he had been exercising, perhaps on an exercise machine.

In late July, the Russians confirmed this suspicion by announcing that Laveikin had indeed got a heart problem and would be relieved by Alexi Alexandrov who was visiting Mir with a Syrian cosmonaut.

Unfortunately this was not the end of the problems. Less than two months after Laveikin left, his original long stay partner Yuri Romanenko was in trouble. Earlier in the year he had seemed to be getting more than his fair share of the long drawn out colds and sore throats that appear to afflict spacemen, then in October he began to sound very tired.

That Romanenko's state of health was worrying others became evident, when his companion Alexandrov began to assume all the communications duties, which up to then Romanenko had monopolised. So it was no surprise, when the Soviets admitted that Romanenko's 300 days in space had begun to affect his performance, necessitating his being relegated to light duty for the rest of his mission. Clearly there is still a lot to be learnt about the biological barriers to long duration space flight.

The Prospects for 1988

The major change to Mir communications in 1987 are summarised in Figure 6. In 1988 it is probable that the Soviets will press forward with the task of providing a geostationary data relay for Mir. If this does not happen they could have problems using Kvant and subsequent science modules effectively. There is perhaps the long shot alternative of switching VHF downlinks to the very effective two frequency phase coherent transmissions which they have begun to use on their ELINT and STORE and DUMP low-Earth orbiters.

OVIET SCENE

Record Breaking Flight

Yuri Romanenko pictured on his way to the launch pad prior to lift-off in February 1987 for his flight which lasted a record 326 d 11 h 8 m. Below, in the latest in his series of Soviet mission reports, *Neville Kidger* **covers activities on Mir during the last four months of 1987.**

Cosmonauts Observe Super Nova

Cosmonauts Yuri Romanenko and Alexander Alexandrov (the "Taimirs") spent much of September 1987 engaged in astrophysical observations with the battery of X-ray telescopes on the Kvant module. By September 22 they had, together with ground controllers, conducted 300 observation sessions of various high energy sources in the sky with 115 of the observations being made of one object – the spectacular naked-eye supernova which had erupted in the Large Magellanic Cloud during the night of February 23/24, 1987.

Medical and psychological teams at the Flight Control Centre near Moscow revealed that the men who also spent a large amount of time studying the surface of the Earth, were in good physical and mental health over this period.

Progress 31, the cargo spacecraft which had arrived at the complex on August 5, refuelled the base module automatically during September 15/16. At 2358 (all times GMT) on September 21 it was undocked from the rear unit of the complex and, at 1222 two days later it was commanded to a destructive re-entry. Earlier, at 1144 on September 23, the Soviets had launched the Progress 32 cargo ship to bring more supplies to Mir. That spacecraft docked with Mir/Kvant/Soyuz TM 3 at 0108 on September 26. The complex was in a 297 x 355 km orbit after the docking.

Progress 32 brought some 2 tonnes of cargo to the Mir complex of which 850 kg was fuel and 315 kg "produce", the balance being oxygen, replacement equipment, scientific equipment, film, research materials and mail for the two men.

It was later reported that during the approach of the cargo ship the new solar panels that had been erected by Romanenko and Alexander Laveikin in June were seen to bend and shake. Soviet experts expressed concern that they might not remain fixed to the station under the impact of a large object.

At 1938 on September 30 Romanenko passed the record set by the Soyuz T-10 cosmonauts in 1984 for the longest single stay in space. The previous record was 236 days 22 hours and 50 minutes and in order to become the absolute record holder, in accordance with the IAF code, Romananko had to exceed this by 10 per cent.

Discussing the passing of the record, deputy director of the mission, Viktor Blagov revealed that the men were experiencing a "certain tiredness" and their working day had been reduced by an hour to five-and-a-half hours with a lower volume of work scheduled.

On October 4 the cosmonauts took part in a TV link-up with the participants of the international space forum which was taking place in Moscow as part of the celebrations of the 30th anniversary of the launching of Sputnik 1.

The men exchanged pleasantries with various Soviet officials and other invited guests such as the US astronauts Owen Garriott, Kathryn Sullivan and Charles Walker.

Bulgarian Cosmonaut Georgi Ivanov asked Romanenko how long the flight was to last but the question was referred to Blagov saying "he never tells us when our flight will be over".

The cosmonauts later participated in other radio and TV link-ups including sessions with French, Hungarian and Japanese participants. The men also sent a goodwill message to the children of Great Britain via representatives of the BBC "Blue Peter" programme.

During their shorter working days the two men continued their routine of

astrophysical, geophysical, medical and technological work. The technological experiments included work with the Biryuza unit to study the dynamics of physio-chemical processes in the microgravity conditions of orbital flight. One experiment studied the formation of "spatial structures during chemical oscillation reactions".

Specialists noted that in late October the observations of the Supernova revealed a sharp change in its spectrum which was attributed to a rapid lightening of the surrounding "envelope" of ejected material.

At 1309 on October 24 Romanenko became the official space flight long duration record holder. He later spoke with Cuban cosmonaut Arnaldo Tamayo-Mendez who had flown with him to Salyut 6 in 1980.

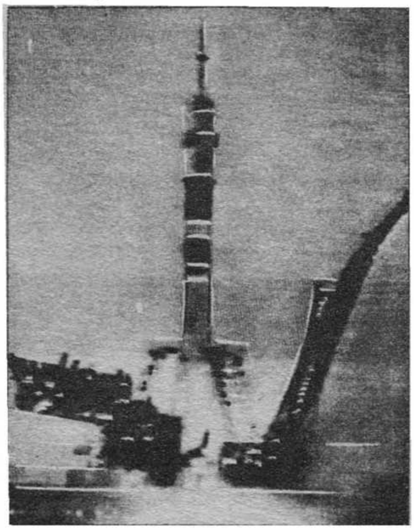
As October gave way to November the cosmonauts continued their work and began packing used equipment and other rubbish into the cargo section of Progress 32. During the first week of November the fuel and oxidiser from the cargo ship were transferred to Mir, followed by the drinking water.

On November 7 the cosmonauts were able to watch the televised parade through Red Square in honour of the 70th anniversary of the October Revolution. Two days later the cosmonauts were completing their unloading of the cargo ship and preparations were underway at the Baikonur cosmodrome for the launching of another cargo spacecraft.

On November 10 an unusual and unique experiment was conducted with Progress 32. At 0309 Progress 32 was undocked from the complex and commanded to withdraw to a distance of 2,500 m. From that distance the cargo spacecraft was commanded to approach the complex and redock at 0547. The Soviets said that the experiment was to "further upgrade methods of holding dynamic operations on orbit". New algorithms for controlling the movement of spacecraft, designed with the aim of cutting the consumption of fuel during the process of mutual search, rendezvous, mooring and docking, were tested.

For the next week the men continued with their experiment cycle. At 1925 on November 17 Progress 32 undocked for the second time from the complex and at 0010 on November 19 its engine was ignited to send it out of orbit to a destructive re-entry.

The next Progress ship was launched at 2347 on November 20. Progress 33 docked with the complex at 0139 on November 23 delivering more food, equipment, fuel and mail. The cosmonauts began unloading the cargo the same day. It included the Mariya apparatus for astrophysics investigations of the Earth's radiation belts, in particular the charged particles in them, and a mirror-beam furnace which the cosmonauts assembled and switched on for the first time by November 26. The small furnace is heated by a lamp and, by means of special optical system, a high temperature is concentrated on a small area. The men were to use the furnace for a series of experiments with different alloy materials. The Soviets linked the experiments to the plans for the launch of "the first specialised technological module".



Launch of Soyuz TM-4 with a three-man crew on December 21 *N Kidger*

On December 3 it was reported that the men had been told to extend their daily exercise on the running track and stationary bicycle by 30 minutes. The cosmonauts conducted some two hours of physical exercises each day to stay in shape and prevent muscle wastage.

That day Romanenko passed the 300 day mark of his space marathon. Viktor Blagov told reporters that the cosmonaut's spirits remained high although he admitted to missing his home, family and friends "very much". His medical condition, particularly his cardiovascular system, was being constantly monitored but showed no signs of irregularities*. After his 300 days in the cramped station Romanenko was said to be looking visibly tired. Microgravity had affected the muscles of his legs and they had shrunk by 15 per cent which was reportedly within "foreseen limits". The veteran cosmonaut's weight was the same as it had been on Earth.

After revealing that the cosmonauts' work schedule had been further reduced, Blagov described a typical day for the two men. Whereas early in the flight the men worked for eight hours a day that time had been halved and the men worked only during the daytime portions of the flight (presumably daytime on Earth).

"Nine hours are allotted for sleep and at least two hours for physical exercise," Blagov said. "Apart from work and meals, the cosmonauts spend their time reading and listening to music. Besides, they like watching Earth through a porthole."

Blagov said that in his opinion it was "expedient to replace crews every six months or even more frequently. But mankind should prepare for landing expeditions on Mars and the round trip there will take 30 months, so as a part of the preparations for such a journey, Yuri Romanenko's 300 days in orbit are a unique and essential accomplishment".

The Soviets also revealed that Progress 33 had delivered 1,000 special envelopes which would eventually carry four date stamps made on October 4, to celebrate the 30th anniversary of Sputnik; November 21, the day they were launched; in orbit; and finally after their return to Earth. The envelopes will then be signed by the cosmonauts and the head of the Soviet Glavkosmos organisation Alexander Dunayev. The envelopes will be sold through a Soviet book agency.

A New Crew for Mir

On December 9 the Soviet press reported that two crews had been presented to them. One of the crews would fly to Mir and take over from Romanenko and Alexandrov.

Crew one consisted of Col. Vladimir Titov (Commander), Musakhi Manarov, Flight Engineer and Anatoli Levchenko (Cosmonaut Researcher and a Merited Test Pilot). The second crew comprised Col. Alexander Volkov (Commander), Alexander Kaleri (Flight Engineer) and Alexander Shchukin (Cosmonaut Researcher and a first class Test Pilot). The crews were to fly to Baikonur on December 10 and begin final preparations for one crew to be launched about two weeks later.

Vladimir Titov previously experienced bad luck on his space ventures. In April 1983 he attempted a totally manual approach and docking of the Soyuz T-8 spacecraft to Salyut 7 after the rendezvous radar boom either failed to deploy or was lost during the launch phase. The attempt failed because Titov was unsure of his approach rates when only 160 m from the station (**Spaceflight**, March 1984, p.137). Titov's next mission was to have started on September 26, 1983 when, with cosmonaut Gennadi Strekalov, he was to have taken over the occupation of Salyut 7 from Lyakhov and Alexandrov. However, a fire at the base of the carrier rocket meant that the two men had to eject in their Soyuz cabin and the plan was abandoned (see **Spaceflight**, May 1984, p.231 for the story of the escape).

**It will be recalled that Alexander Laveikin was brought home early from the current expedition when irregularities in his heart beat were detected. The Soviets have since said that there were no problems with the cosmonaut and have passed him fit for future flights*

Soviet cosmonauts Alexander Alexandrov, Yuri Romanenko and Anatoly Levchenko pictured after arriving in Star City, outside Moscow, from Baikonur spaceport on January 12. *Novosti*

In 1986 Titov was training with Alexander Serebrov for the next flight to Mir but, as one Soviet commentary put it "Yuri Romanenko and Alexander Laveikin were destined to make that flight".

So, if the launch and docking of Soyuz TM-4 was a success Titov would take over a fully functioning space station as had been planned for him to do in 1983. Ironically, the Flight Engineer that he and his partner Manarov would be relieving was the same Alexander Aleksandrov as he would have relieved in 1983.

The Soviets have given no reason to date as to why the Titov/Serebrov partnership was broken up and the Flight Engineer replaced with Manarov, a rookie cosmonaut.

Manarov was selected as a cosmonaut in 1978. Born in Baku, Azerbaijan, he had no previous assignments to flight crews before Soyuz TM-4. He was a 1974 graduate of the Moscow Institute of Aviation before he worked at the space systems development centre, training at Star Town and working at the Flight Control Centre. Manarov had been in contact with Romanenko and Laveikin in March 1986 by radio link whilst working at the FCC.

Anatoli Levchenko's place on the Soyuz TM-4 flight crew was requested by the Ministry of Aviation Industry, He began space training in 1978 and was the second highly experienced test pilot flown for that ministry (the first was Igor Volk on Soyuz T-12. Volk has since been confirmed as the Chief Test Pilot for the Soviet space shuttle). Levchenko is a part of the group preparing for the Shuttle and the flight on TM-4 was explicitly stated as necessary for that programme. Western observers had expected the TM-4 crew to be Titov, Serebrov and Poliako who was the reserve for Atkov on Soyuz T-10 in 1984.

The reserve crew (the prime and back-ups were finally approved on December 20) was headed by Alexander Volkov, who flew on Soyuz T-14, Alexander Kaleri who is a graduate of the Moscow Institute of Applied Physics and Alexander Shchukin who presumably is in the same group as Levchenko.

For the first time, the Soviet media broadcast an interview before the launch with the head of the State Commission, the man who chairs the meetings that control spaceflight in the Soviet Union. As one Soviet journalist said: "Kerim Aliyevich Kerimov told us that he had seen more than 300 space launchings and had been present for every launch vehicle assembly."

At dawn on December 19 the carrier rocket for Soyuz TM-4, with the spacecraft at its tip was rolled out to the launch pad. The Soviets announced that the launch was set for 1118 on December 21 and that the commander and flight engineer would stay aboard Mir leaving Romanenko, Alexandrov and the cosmonaut researcher to return to Earth after a joint flight of one week.

In space, Romanenko and Alexandrov had increased their use of the Chibis vacuum suit to simulate gravity to prepare them for their impending return to Earth and, at 0816 on December 19, Progress 33 was undocked from the rear of the complex and later commanded to a destructive re-entry. All was ready for the historic first full crew rotation on a space station.

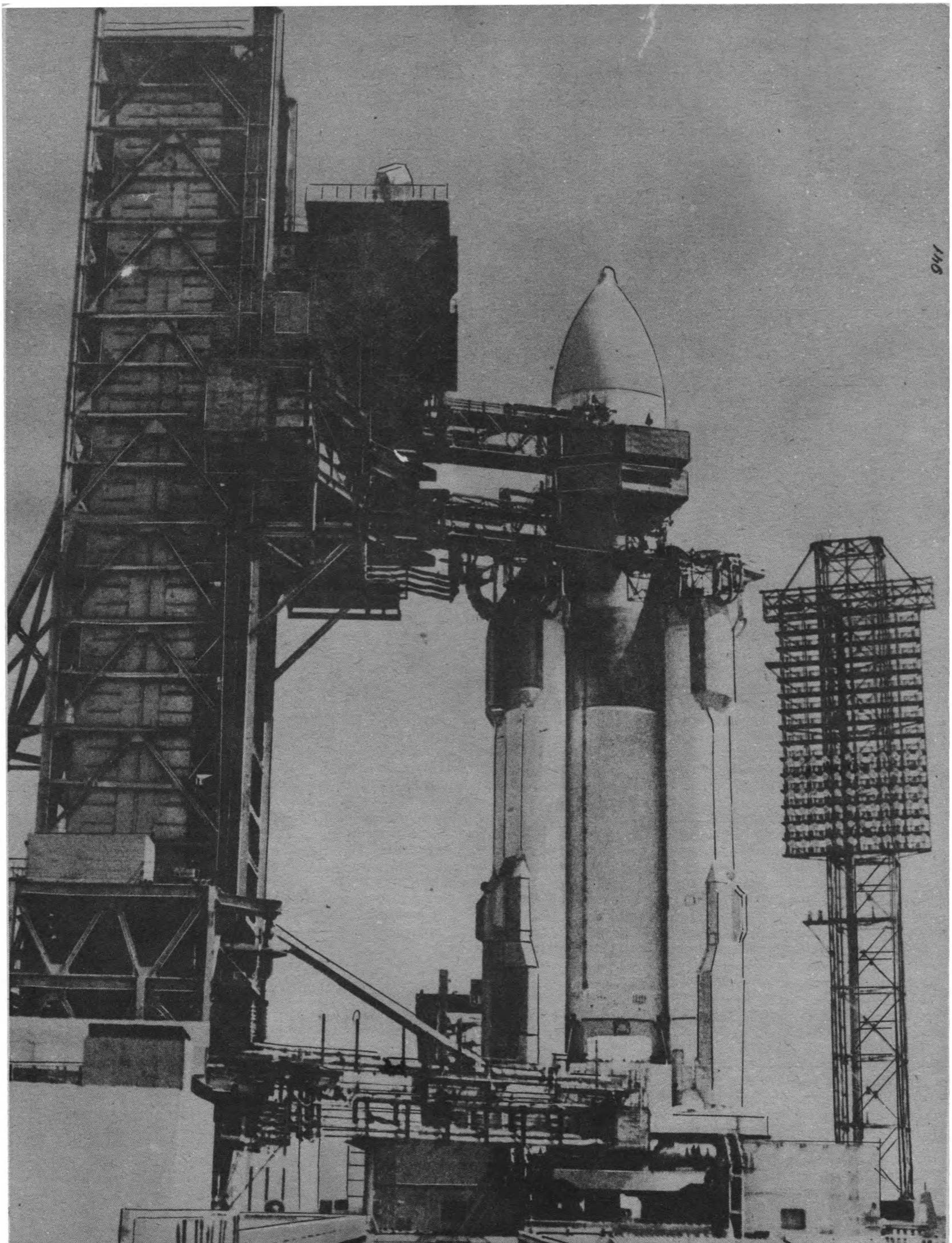
Soyuz TM-4 in Space

Live TV coverage was given from a snow-covered, foggy Kazakhstan steppe as Soyuz TM-4 was launched on December 21 at the scheduled time. As soon as the spacecraft with cosmonauts Titov, Manarov and Levchenko onboard had entered orbit Romanenko sent a message congratulating them on the launch and said he was looking forward to their arrival. The docking was scheduled for December 23.

Between the launch and the docking were several manoeuvres to raise TM-4's altitude to that of the station and, with 40 minutes to go to the scheduled docking time FCC heard Titov (call sign "Okean") say that he had seen the complex in space at 35 km distance for the first time. Soon the station and TM-4 were just 1 km apart with a closing speed of 4 m/sec. At 1228 Titov began TM-4's flight around the complex to reach the rear docking unit. This lasted seven minutes. TV pictures relayed to FCC showed the final approach and the docking itself, which occurred at 1250:50.

At 1420 the hatches between the ship and station were opened and the new occupants of Mir floated in to assume their tenancy. The flight controller, former cosmonaut Valeri Ryumin had instructed the new crew not to show any "excessive emotion". He reminded Titov's crew that the two men in space were "very much of space" whilst the new men were "still too much of Earth".

The Soviets said that Romanenko, Alexandrov and Levchenko would return to Earth on December 29 and



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that Titov and Manarov would stay in space for one year on a mission involving the receipt of another module, addition of more solar panels by means of EVA and visits by other crews, including international ones.*

During the first days of the joint flight the men continued medical studies and the couch used by Levchenko on Soyuz TM-4 was transferred to TM-3. The two "old hands" showed their successors the systems of the station. "We shall show you everything there is in this house," Alexandrov said. "Let it be as dear as home to you".

The men also conducted some processing experiments on the electrophesis unit and grew protein crystals in the Ainur installation. The Okean crew had also delivered fish in an aquarium, tissue cultures of vegetable and animal origin and decorative plants to the station both for scientific and aesthetic reasons.

The Taimirs showed the newcomers how to operate the Kvant module and also shared their experiences on conducting operations that require spacewalks.

By December 28 the joint flight was approaching its end. A Soviet newspaper report gave the impression of some "testiness" aboard the complex when it said that after the crews had been asked by FCC to confirm that they had not forgotten to load some results of experiments into Soyuz TM-3 one of the men radioed that "all superfluous personnel" should be removed from the FCC hall. "We have our instructions, and everything will be delivered in the best possible condition. Since yesterday we've been rushing around like squirrels in a wheel. Experiments, comments on experiences, loading – you name it, we've been doing it. We've still not had time to pack our personal things. And you are distracting us with unnecessary talk."

The comments were picked up by western newspapers who promptly reported a verbal mutiny in space!

An official statement concerning development of the Soviet space shuttle was made during a press conference given by cosmonaut Yuri Romanenko in January.

Alexander Dunayev, Chairman of Glavcosmos, stated: "We are working on the space shuttle; we are making significant progress which is no longer purely experimental. We are completing the development phase and I believe the first orbital test flight will be made very soon."

The next Energia launch was expected before the end of this month (March). The third Energia launch will be used to carry in an automatic flight the Soviet shuttle probably during the second half of this year. If this test flight is a success, then a manned space shuttle could fly in 1989.

Left: Picture of the Energia rocket as it was prepared for its first flight in May of last year.

Novosti

The Soviets also reported that a dress rehearsal had taken place at the scheduled landing site some 60 km north-east of the town of Arkalyk in Kazakhstan during which the role of the descent cabin was played by a parachutist with a radio transmitter.

Return to Earth

By 0100 on December 29 the three cosmonauts returning in Soyuz TM-3 had bid farewell to Titov and Manarov and sealed themselves into the craft. Pictures of the farewell was shown later on TV.

At 0555 Soyuz TM-3 undocked from Mir's front docking unit. Retrofire was set for about 0820. At 0823 Soviet radio reported that the descent had begun and that just before 0850 the descent cabin had separated from the instrument section.

TV cameras on a helicopter picked up the descent cabin under its parachute and tracked it until it disappeared into fog. The landing occurred out of view of the TV at 0916. Strong gusts of wind had seemingly blown the cabin onto its side. The gusts – as strong as 25 to 30 m/sec – made it difficult to erect the medical tent so the plan was scrapped and rescue workers helped Romanenko out of the cabin and he was carried to a seat where, although he looked weary, he gave an impromptu interview and described his happiness at coming back to Earth "to snow-covered Kazakh soil, to friends and comrades".

Romanenko described how Alexandrov had "endured" the early part of the flight but that by the end of it he had been conducting experiments and taking pictures literally to the last second.

The rescue team helped Alexandrov and Levchenko to a waiting helicopter. Romanenko was carried on a stretcher but was soon seated upright. The weather seemed to be deteriorating with gusts of wind whipping up the snow.

TASS later reported the landing and said that it had occurred some 80 km from Arkalyk. The cosmonauts were flown to the town by the helicopter and then were flown onto Baikonur on a separate plane. Levchenko left the two other cosmonauts to fly "up front", piloting himself as an apparent test of his ability to fly a plane after a space flight.

At Baikonur, Romanenko and Alexandrov were greeted by their families, a first for the Soviets – families are usually re-united at Star Town. The Soviets said that the families would now spend the New Year together.

On December 30 Soviet TV showed pictures of Romanenko walking with his wife in the grounds of the hotel at Baikonur. That day also the three cosmonauts held a press conference at which it was reported that Romanenko had walked to his room unaided, undressed and had supper the previous night. Earlier that morning the cosmonauts had been involved in medical checks.

Alexandrov revealed that he had adopted a slightly less demanding programme of physical exercise to his commander to assess the diffference it made. The fact that the cosmonauts were not "jumping and running" was because they were following the strict medical routine. Alexandrov also said that "there was no question of vestibulary disorders ... first because of previous experience, and, second because of the scrupulous fulfilment of the planned programme (of physical exercise)."

Romanenko also told the reporters that before the descent "the three of us had never met before at a training session or anywhere on Earth". It was also the first time in space flight history that one descent had brought down three men to Earth who each had been in space for different times:

Romanenko – 326 days, 11 hours 8 minutes.
Alexandrov – 160 days, 7 hours 17 minutes.
Levchenko – 7 days, 21 hours 58 minutes.

This total brought Romanenko's individual accumulated total of time spent in space to 430 days, 18 hours and 21 minutes. He now holds all the records for individual and accumulated duration in space.

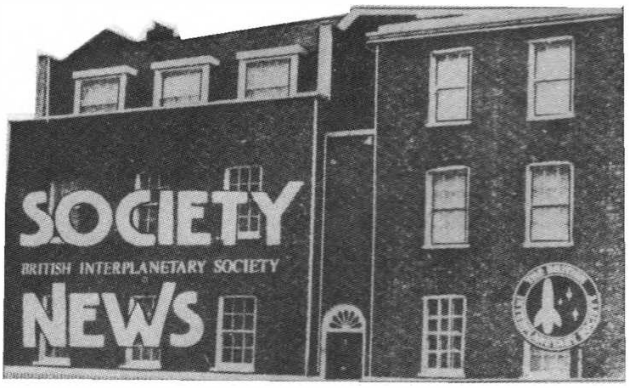
"Okeans" Begin Work in Space

On December 30 Titov and Manarov began their planned year-long stay in space by going for a short flight in Soyuz TM-4, undocking it from Mir/Kvant's rear port at 0910. The station was then automatically rotated through 180 degrees and the two men redocked with the front port of the base unit at 0929. After floating back into their new home the men settled down to the routine of orbital life.

They were the first cosmonauts since Romanenko and Grechko exactly 10 years earlier to celebrate the New Year in space. They first crossed the "New Year zone" at 1157 on December 31 and at midnight Moscow Time they were orbiting above the Cape of Good Hope.

For Titov, January 1, 1988 was a double celebration, it was his 41st birthday. The cosmonauts were given the day off to rest and speak with their families and friends before they began the work programme for 1988 in earnest.

**It was announced on December 25 that two crews were in preparation for a launch on June 21 1988 for a 10 day mission to Mir The two crews are Vladimir Solovyov, Viktor Savinykh and Bulgarian Alexander Alexandrov The second crew consists of Vladimir Lyakhov Andrei Zaitsev and Bulgarian Krasimir Stoyanov (a contradictory Bulgarian report said that the second crew consisted of Lyakhov Serebrov and Stoyanov)*



Society Contributes to Major Report by House of Lords

In May 1987, the Society welcomed an invitation to submit its views to the House of Lords Committee on 'United Kingdom Space Policy' sitting under the Chairmanship of Lord Shackleton.

With the Committee's work now completed and its Report* recently published it is gratifying to see forthright endorsement of the main planks of long-standing BIS Space Policy by such an august body as the House of Lords Select Committee on Science and Technology.

In Volume II of the Report four pages are devoted to the Society's submission which critically examined UK space involvement (or lack of) with poignant comments on the right direction for the UK's future work in space.

On the subject of 'Launch Capability', the BIS submission called for continuing support for the Hotol project as follows:

> In the medium-term, UK launching requirements are tied up with the ESA programme. However, a new opportunity, with the advent of Hotol, could not only revolutionise the situation in the longer term but prove of considerable significance to industry very rapidly. Figures for Hotol performance are not publicly available but internal enthusiasm for it within British Aerospace indicates that it should be well-worth supporting. The emergence of comparable projects, appearing at roughly the same time in other parts of the world, is no accident and also indicates that this is probably an area ripe to be exploited. As it is one in which our country does not start from a rear position, the evaluation of Hotol may present a prime opportunity to redress lost opportunities of the past.
>
> This indicates a need to inaugurate and support a technology and development programme aimed at analysing all aspects of Hotol feasibility and, politically, to determine the full nature of the international options available.

The Society's submission described industrial involvement in space generally as "an almost wholly untapped area" pointing out "the importance of Government support to industry to enable it to undertake fundamental research and development studies on forward-looking projects". The Society put the view that:

> Large sections of UK industry will eventually be involved in participation in the benefits derived from space exploitation. Thus, industry is an important area but one where it is not immediately easy to convince some companies of these benefits. For example, UK pharmaceutical companies appear to show little interest in what is happening.
>
> On the other hand, some of the newer sections of industry e.g. in computers and robotics, show a keen awareness and seek to be involved. This applies to many other modern firms in a variety of fields, in most cases involving relatively small staff numbers at present, but which have the potential for ready expansion and thus may introduce a most valuable input to space involvement.

House of Lords Select Committee on Science and Technology, United Kingdom Space Policy, HMSO, £7.00


Lord Shackleton.

The Society's Submission ended with a call for increased resources, pointing out that the French budget on space now exceeded eight times that of the UK: "There is no doubt that the overall UK space funding is too low by any standards."

It must be apparent to most people that our country, which relies on technology for its well-being, must devote a reasonable part of its resources in exploring areas where our future industrial and scientific bases may be utilised, maintained or expanded. To do otherwise would eventually prove self-defeating.

The House of Lords Report is highlighted on p.124 of this issue. Its enthusiastic and unequivocal support for an expanded UK space programme is welcomed by the Society. It is critical of Government dithering on space policy and offers good advice to the Government for urgent action. The Society is pleased to have been associated with the preparation of this Report.

'Blue Streak' – Lesson For The Future

Mr. C.H. Martin of British Aerospace Space and Communications Division gave a talk on the Blue Streak Launch Vehicle at a meeting chaired by the President at the Society's Headquarters on December 2 and attended by 40 members.

The talk covered the early period of the project in the mid 1950's, the conversion of the vehicle to become the first stage of Europa I and II Satellite Launch Vehicles for ELDO in the early 1960's and its cancellation in 1973 after 11 successful launches. Sixty slides giving details of the vehicle's construction and test facilities were shown.

A film of the project during the last quarter of 1958 was presented, which depicted the construction of the test sites at Spadeadam in Cumbria, Hatfield in Hertfordshire and Woomera in Australia together with the vehicle manufacturing facilities at Stevenage and Hatfield and those for the Rolls Royce engines at Derby and Spadeadam.

In the audience were several members who had worked on the project including Mr. C.R. Turner (President) and Mr. G.W. Childs (Vice-President). During their careers in space both Messrs. Childs and Martin were at one time Chief Designer of the Blue Streak project. Mr. Turner spent part of his career as a Manager in the Dynamics Department of one of the project Design Offices in London.

As the UK is again at the cross roads in its space programme the lessons on Blue Streak were particularly relevant. It should be remembered that it was only 15 years ago when the UK led Europe in launch vehicle technology. As predicted by the late Val Cleaver of Rolls Royce, cancellation of Blue Streak lead to the virtual demise of large-scale launcher activities in the UK. Although the prophecy has turned out to be true, it should not be taken as meaning that we are out of the business forever. Support for Hotol could reverse the serious decline that has taken place in UK launch capabilities.

UK 'Deeds of Covenant' Boost Appeal

Members who are liable to UK income tax and have completed Deeds of Covenant in respect of their subscriptions to the Society will be pleased to know that the benefit to the Society amounted to £4,161 in 1987.

This amount has been allocated to the Society's Building Appeal, thereby increasing the Fund total to over £12,000.

All members who are liable to UK income tax are urged to complete a Deed of Covenant. The appropriate form is available from the Society and is simple to complete. In this way the Society is able to benefit financially at no cost to the member.

The Society gratefully acknowledges the many individual donations to its Building Appeal that it is currently receiving. Every contribution brings us one step nearer to our £80,000 target. Many letters accompanying donations bring their own words of encouragement:

> Please find enclosed cheque for £8 which is a donation to the Building Appeal Fund. Good Luck!.
>
> Liverpool

> Please find enclosed the order form complete with the sum of £10 for your 'Space for Space' Appeal. I hope you find this small donation useful. I would also like to say what a fantastic job you do with ***Spaceflight***.
>
> Devon

> Also enclosed is a donation to the BIS Building Extension Appeal – like the Mir space station the BIS is also expanding, good luck with that.
>
> Northampton

> I am pleased to enclose a cheque for £10 towards the Building of the Extension on to the rear of the Society's premises.
>
> Channel Islands

> Please send me a copy of the September 1987 issue of the JBIS. My cheque includes a donation of £8 to the BIS Building Appeal.
>
> Hants

> Please find enclosed M/O for the following, including £10 donation to the Society's Building Appeal.
>
> Sth. Australia

> Please put the balance of my cheque (£11) towards your Building Appeal.
>
> Kent

Black Knight Symposium

The 'History of Black Knight' Symposium will take place at Society headquarters on March 23, 1988 from 10 am until 5.30 pm.

Chaired by John Becklake of the Science Museum the following is the provisional list of papers to be presented:

Overview of Black Knight Project (Mr. H. Robinson), Black Knight – A Contractor's View (Mr. J. Scragg), Propulsion for Black Knight (Mr. D. Andrews), Black Knight – Upper Stages (Mr. J. Harlow), Black Knight Payloads (Mr. R. Dommett), Proposals for the Development of Black Knight (Mr. H. Robinson and Mr. R. Bain)

There will also be a Black Knight film and ample opportunity for discussion. A buffet launch and refreshments will be served.

The Registration fee is: members £10, non-members £12. Numbers will be strictly limited so please apply for form as soon as possible, enclosing SAE.

Obituary

F. T. Davies

It is with deep regret that we record the death on January 1, 1988 of Frank T Davies, a Fellow of the Society since 1946.

Mr. Davies worked at Handley Page Limited from 1950 to 1970, where he carried out original and innovative work on the stability and control of the Victor aircraft, which first flew in 1952 and is still in RAF service, and on the first version of the HP 137 Jetstream, which is currently a highly successful aircraft with British Aerospace.

In accord with Frank Davies' wish his family requested that, instead of flowers, donations should be sent to the Society's Building Appeal. We are pleased to acknowledge the receipt of a total of £129 donated in his memory.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

5 March 1988, 10.30 am — **Visit**

UNIVERSITY OF SURREY

A tour of the UoSAT Spacecraft Engineering Unit for BIS members. Further details from: Executive Secretary, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Please enclose SAE Numbers will be restricted so please apply in good time

9 March, 1988, 7-9 pm — **Lecture**

HOTOL – A SPACEPLANE FOR EUROPE

G.P. Wilson

Members only. Please apply for ticket, enclosing SAE, in good time.

23 March 1988, 10-4.30 — **Symposium**

HISTORY OF BLACK KNIGHT

An all-day Symposium. Refreshments will be provided and as numbers are limited early registration is advised.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

4 June 1988, 10-4.30 — **Symposium**

SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

6 April 1988, 7-9 pm — **Film Show**

RETURN TO KENNEDY

The following films will be screened:

Spaceport USA
Doorway to Tomorrow
In the Time of Apollo
The World was There

The meeting will take place in the Society's conference room. Admission is by ticket only. Members should apply in good time enclosing an SAE.

4 May 1988, 7-9 pm — **Lecture**

HISTORY OF THE ROYAL OBSERVATORY

A.J. Perkins

Flamsteed, Halley and Bradley, the first three Astronomers Royal, need no introduction to anyone with an interest in the history of astronomy. The seventh Astronomer Royal, G.B. Airy, has his own renown but his life and work at the Royal Observatory, stretching over 46 years, are not well documented. Tracing the history of the Observatory at Greenwich from its foundation in 1675, Mr Perkins will show in his talk how Airy's achievements and setbacks have affected the development of the establishment up until the present day.

Admission by ticket only. Members should apply in good time enclosing an SAE.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

CORRESPONDENCE

Government Attitude on Space

Sir, I am surprised that none of your correspondents has mentioned that, apart from a somewhat boorish approach to UK space interests at the ESA meeting last November, Kenneth Clarke launched an amazing attack on 12 friendly governments all of whom he accused, in effect, of incompetence and a total disregard for the interests of their taxpayers. The strictures he thus laid upon them for supporting space activities were hard to credit: one can hardly imagine anything designed to be more offensive.

There is no doubt, from earlier comment, that the Minister went into the ESA meeting badly advised and expecting support from a number of other countries. He had intimated as much. In the event, his manner must have been so abrasive that the other 12 Ministers recoiled and stuck together as never before with the result that agreement was reached, ignoring the UK, on every item without difficulty!

Successful negotiations on the international scene are often matters of attitude, sophistication and understanding, rather than pure words. An aggressive attitude and an argument that "money should be spent on hospitals, not space" – as though one is an alternative to the other – show a degree of naivity hard to excuse and which, like the Grand Old Duke of York, denotes leadership from the rear. One can discern several reasonable strands in what the Minister said, but did his performance go beyond what Mrs Thatcher had expected?

The basic weakness of the UK programme is that it lacks a well-understood national strategy and policy. If such a policy could be ingrained in the political leadership, the erratic moves which have bedeviled UK space activities for decades now would not recur.

P.R. FRESHWATER
Henley-on-Thames, Oxon, UK

Positive Action

Sir, It is refreshing to find someone in Britain who is doing something positive in the space industry, unlike the very short-sighted attitude of the UK government. I look forward to the next issue of ***Spaceflight*** and wish the Society and all its members a Happy New Year.

S.R. SPRINGETT
Oakham
Leicestershire, UK

Promoting Space

Sir, I have a great deal of respect for the BIS. I consider it a unique source of valuable information, which I apply to promoting space in whatever way I can promote it. I also consider it an invaluable supply of informed speculation and of inspiration. The BIS's members were dreaming of space flight long before it was achieved, when they wandered in a darkness far darker than anything experienced by space flight dreamers of today, no matter how poor the state of space programme in the United Kingdom and the United States might appear to be (in the UK at least the government says it will not spend money on space – in the United States big space goals are proclaimed to spice up speeches, then die a lingering death). This early faith in the dream is almost impossible to grasp; it took courage, and perhaps a little insanity!

I would suggest to Mr. Lister (***Spaceflight***, January 1988, p.29) and all other members that they translate the information and inspiration provided by the BIS into efforts to promote space on their home fronts. They can do this by talking before groups, starting a local group of enthusiasts, or pestering the media through letters to editors. I have done all these things, with very nice results. We all need to *work* toward our goals – just paying dues is not nearly enough.

I believe the BIS shows a great deal more integrity than some other organisations, ostensibly promoting space, by printing letters like that of Mr. Lister. This shows that member input is respected. I have belonged to space organisations where member criticisms were received with hostility.

Please keep up the good work by publishing your fine publications and sponsoring your programme. I will take what I learn from these and disseminate it to a wider public

DAVID S F. PORTREE
John W. Young Planetarium
Orlando Science Center
Florida, USA

Government To Assess Hotol

Sir, I enclose a copy of the reply to a letter I sent to my local MP (Sir Peter Hordern – Horsham, Conservative) concerning British space activities. The letter comes from John Butcher MP and seems less decisive than the statements made by Kenneth Clarke last October and November. I was encouraged to write before Christmas and hope that many other members of the BIS have done the same.

JULIAN G. S. JAMES
West Sussex, UK

Ed. *The reply from Mr. John Butcher, MP, Parliamentary Under Secretary of State for Industry, included the following reference to Hotol. In other respects it recounted the UK position at ESA's November 1987 meeting as published in* ***Spaceflight****, February 1988, p.69:*

Hotol was not considered at the ESA meeting as it is not one of the ESA programmes At present, it is at a very early stage, and a "proof of concept" study with Government financial backing is near completion When the results have been assessed, the Government and industry will consider the position

Inheriting A Space Initiative

Sir, I would like to inform Society members of my contribution to the many objections to the current government's intransigence towards the National Space Plan. I wrote to Mr. John Butterfill my local MP, in early August, who then passed my letter to Mr. John Butcher MP at the Department for Trade and Industry.

I outlined the possible economic implications for such a policy and questioned the claims of the Prime Minister.

As the decision to retain the current ESA contribution was revealed last autumn, Society members should now concentrate on communicating our common grievance to the highest places. Mr. K Gottschalk (***Spaceflight***, February 1988, p.69) mentions this point.

As a final tip, I would recommend members should also write to the MPs for their neighbouring constituencies. My MP, who represents Bournmouth West, appears to have little determination to argue the case, yet the nearby Bournemouth East MP has joined a cross-party lobby for the National Space Plan.

I am aged seventeen, and those in my generation interested in astronautics will need to inherit a space initiative that we can build and draw upon to continue space exploration.

BERNARD STEDMAN
Wimborne, Dorset, UK

CORRESPONDENCE

Encouraging Response from MP

Sir, I decided to take your advice by writing to my MP (Sir Gerard Vaughan) to condemn our government's short-sighted attitude towards space research funding. As a younger member of the Society, I informed my MP that I was learning European languages in preparation for joining Britain's brain drain!

I received a reply from the House of Commons. On reading it, however, I discovered that I must have written to one of the few Conservative MPs in the country who agree with BIS policy, Nevertheless, let this not deter other members from writing to their MPs, for I found it very gratifying to be assured that efforts were being re-doubled to fulfil our goal. It convinced me that I was not flogging a dead horse.

J.S.P. WORDIE
University of Reading
Berkshire, England

New Concept in Hypersonic Flight

Sir, One of the problems facing designers of hypersonic air/spacecraft is the immense heat generated by friction as the vehicle encounters molecules of atmosphere. At speeds of Mach 6-7 the temperatures are already very high and at the speed required for a vehicle to go into low Earth-orbit (approx. Mach 23) the heat is tremendous. The problem is the same when a vehicle re-enters the atmosphere after orbiting the Earth.

I would like to suggest a new concept which would turn these problems to our advantage. Basically, what I am suggesting is that the tremendous heat encountered at hypersonic speeds be converted to electric energy and then converted back to thermal energy and used for propulsion.

The concept would require us to build a round or frisbee-shaped vehicle, part of which would revolve around a central axis thereby exposing as much of the leading edge as possible to the heat and at the same time having as small a surface as possible facing the direction of flight. By making the vehicle round we could use the entire leading edge (the whole 360 degrees) to absorb as much thermal energy as possible.

In other words, what I am proposing is that we, instead of trying to shut the heat out, conduct it through mainly the leading edge to an inner coolant gas or liquid and use this gas to drive turbines connected to generators, providing electrical energy to specially designed electrical rocket engines "burning" atmospheric gases.

The concept calls for the development of a material which can withstand the enormous temperatures and conduct large amounts of heat through the material and to the inner coolant liquid of gas.

Furthermore the concept calls for the development of small, light and highly efficient turbines, generators and electrical rocket engines.

The arrangement would be something like the spokes of a wheel. With the generators in the centre, then the turbines with a system for carrying the gas or liquid to the leading edge of the air/spacecraft and back to the turbines.

The electrical rocket engines too would be movable around a central axis to be able to provide thrust in any direction.

At a certain speed (the critical speed) the heat encountered by the vehicle will be so high that the vehicle will start to produce more electrical energy than it consumes. In effect it will become a flying power-station producing its own energy as it flies along!

For flights below the critical speed and for flights outside the atmosphere, the vehicle would have to use an on-board fuel. (Unless new types of devices for storing large amounts of thermal and/or electrical energy can be developed). For flights above the critical speed no fuel would be required. The air/spacecraft could, for all practical purposes, fly indefinitely.

The round shape of the vehicle, necessary for the propulsion system, would have other advantages. The cockpit could be movable and the vehicle could fly in any direction. No rudder, elevators or ailerons would be required. These would all be replaced by the electrical rocket engines, which also would provide thrust for acceleration and deceleration.

When I first started to think about the design of small, very efficient turbines and generators in 1984 it soon led me to think about superconductors. Not knowing anything about the subject and never having heard of the so called BCS theory until the summer of 1986, I had to develop my own theories and solutions as I went along. I have now found a solution to these particular problems without having to use liquid helium.

If the discoveries by Bednorz and Müller should lead to further breakthroughs, to room-temperature superconductors and enable us to make superconducting generators of this compound – it would be an advantage, but not absolutely necessary for this concept.

R. SALLSTEDT
Stockholm, Sweden

Spaceflight

Sir, I would like to thank all of you involved in the organisation of the Society, and especially those involved in putting together ***Spaceflight*** magazine which gives a very well rounded look at advances in space science throughout the world.

PAUL J. BOOS
Edmonton, Canada

Sir, I congratulate you on the continued magnificent production of ***Spaceflight***. The magazine goes from strength to strength and is now very attractively presented. I could not survive each month without my regular "dose" of it!

GRAHAM T. NEWMAN
Manchester, England

Dial-In for Satellite Info

Sir, The Dallas Remote Imaging Group is an amateur organisation comprised of data processing and telecommunications professionals with an interest in capturing imagery from the NOAA, Soviet Meteor APT and GOES weather satellites. Our group does digital image processing on the ingested data using IBM PC and Commodore Amiga personal computers. The Dallas Remote Imaging Group operates a remote bulletin board system (214-394-7438) called the Datalink RBBS system. This is an open system that carries the latest Keplerian elements for over 50 satellites, NOAA/NESDIS APT notes, satellite tracking data, intelligence briefs from the Kettering Group, updates on Soviet military and civilian Cosmos launches, and programs for the digital image processing of satellite data.

The Dallas Remote Imaging Group welcomes all readers of ***Spaceflight*** to use Datalink RBBS for their educational enjoyment. It may be accessed with any personal computer or ASCII terminal by dailing 214-394-7438 at 300 or 1200 bits per second. The system is operated 24 hours daily and has a user base worldwide. Datalink RBBS contains a shadow copy of the electronic bulletin board operated by the National Oceanic and Atmospheric Administration (NOAA) and has weekly updates on new satellite launches.

DR. JEFF WALLACH
Texas, USA

'Small' Soviet Shuttle (Hermes-Class Spaceplane)

Sir, While the existence of the large Energia-based shuttle is now public knowledge, there are conflicting reports about the simultaneous development of a Soviet Hermes-class spaceplane to be launched atop the SL-16 Medium Lift Launch Vehicle (see ***Spaceflight***, November 1987, p.370).

The four Cosmos scale models launched between 1982 and 1984, which bore an uncanny resemblance to the US X-24 lifting bodies, have generally been regarded as scaled-down versions of the spaceplane. But during a recent visit to Paris, cosmonaut-designer Konstantin Feoktistov refuted reports about the existence of such a Soviet spaceplane and said that the scale modules were only flown to study the thermal protection system and aerodynamics for the large shuttle's atmospheric reentry [1].

Nevertheless, a recent series of heavy payloads launched by SL-16 (Cosmos 1767, 1820, 1871 and 1873) have also been linked to the spaceplane programme. These 10 ton objects, which did not perform any manoeuvres and all decayed after about a fortnight in orbit, could be interpreted as "boilerplate" models of the spaceplane, designed to man-rate the SL-16 and furnish data on the dynamic characteristics of the SL-16/spaceplane stack.

The US Defence Department has been adament for several years that a Soviet spaceplane is under development, mainly for military purposes. The 1987 edition of *Soviet Military Power* cites such applications as "quick-reaction real-time reconnaissance missions, satellite repairs and maintenance, crew transport, space station defence, satellite inspection and, if necessary, negation". Obviously, only time will tell who is right.

BART HENDRICKX
Kapellen, Belgium

Reference

1 *Air et Cosmos*, October 17, 1987, p 39

Soviet Launcher Designations

Sir, I am extremely interested in space flight and have bought several copies of ***Spaceflight*** magazine, which I have found to be very informative. In the 'Satellite Digest' in the December 1987 issue, reference is twice made to a Soviet 'J-1' launcher. I know of six classes of Soviet launchers, the A, B, C, D, F and G classes, but I have never heard of the 'J-1' (and 'H' and 'I') before.

The only presumption I can make is that the 'J-1' is the new Soviet medium launcher spotted by American spy satellites and designated SL-X-16.

FRANCIS AISH
Winchester, England

Sir, While reading through the December issue of ***Spaceflight*** I noticed that the launch vehicle for Cosmos, 1873 was listed as possibly 'J-1'. Could you please explain this designation along with 'F-2' and 'D'.

I. PATTERSON
Northumberland, UK

Mr. Bob Christy, who compiles 'Satellite Digest', has provided the following information:

'J-1' as a Soviet launch vehicle designation continues the type-classification set-out in 1969 by the late Dr Charles Sheldon. In 1982, the US Congressional Report 'Soviet Space Programs: 1976-80' indicates, on page 56, that Sheldon intended 'J' to be used for the next, new type of rocket. As Mr. Aish surmises, it does indeed represent the 'SL-X-16', now re-designated 'SL-16' since it has become an operational rocket.

'Energia' should become SL-17 and may, by general consent become the 'G' vehicle in the Sheldon system, a designation originally set aside for the postulated 'Webb's Giant' lunar launcher of the late 1960's.

The 'SL-' prefix, which stands for 'Space Launcher' is applied by the US Department of Defense as new Soviet launch vehicles come into being. It is nondescript, and can provide a convenient escape route from having to identify the family to which a rocket belongs as there is no relationship between the numeric suffix and a rocket type. For example, the Sheldon 'D' series consists of the D-1 rocket used for the original Proton satellites (SL-9), the early version of the D-1-e planetary launch vehicle (SL-12), and the latest geosynchronous-orbit and planetary D-1-e (SL-13). SL-13 is sometimes shown as D-1-h where the '-h' denotes a presumed high-energy upper-stage.

A precise relationship between the Sheldon system and some of the SL-designations is unclear, if indeed all of the SL-variants actually exist. The difference between the SL-1 and SL-2 versions of the 'A' vehicle may have come about because of a presumption (at the time) that the rocket which lifted the half-tonne Sputnik 2 and the 1.3 tonne Sputnik 3 must have been larger than that for the 83 kilogramme Sputnik 1.

Listed below is a conversion between the two series:

Sheldon	SL-	Examples of use
A	1	Sputnik 1
A	2	Sputnik 2 & 3
A-1	3	Vostok, early Cosmos reconsat, Meteor
A-2	4	Voskhod, Soyuz, Progress, Cosmos reconsat
A-2-e?	5	(obscure SL-designation)
A-2-e	6	early lunar/planetary probes, Molniya
B-1	7	small Cosmos and early intercosmos (now redundant)
C-1	8	current small Cosmos, Intercosmos, Cosmos navsat
D-1	9	Proton, Salyut, Kvant
D-1-e	12	heavy lunar, planetary probes
D-1-e	13	Raduga, Gorizont, Ekran
F-1	11	Ocean surveillance (radar and electronic)
F-2	14	later Meteor-2, Meteor-3, oceanographic Cosmos
G	15	speculative, large lunar rocket
G?	17?	Energia?
J-1	16	new, medium-lift rocket
?	10	(obscure SL-designation from around 1965/66)

Note that 'E' is not used in order to avoid confusion with the '-e' stage of the A-2-e and D-1-e, 'H' is absent for a similar reason as Sheldon anticipated a possible high energy, liquid oxygen/hydrogen upper-stage for the 'D' vehicle. 'I' is avoided because of potential confusion with the figure '1'.

Mir Docking Unit

Sir, I would like to respond to Daniel Fischer's letter (***Spaceflight***, January 1988, p.28) concerning the Mir space station.

The point I tried to make regarding the new multi-docking unit is that I believe that any craft approaching Mir will have to use the three docking collars that retain conical receptacles (the rear, forward and upper collars).

A heavy Cosmos craft that docks with the upper collar would soon after be transfered to one of the side collars via the Ljappa arm system. A heavy Cosmos docking at the forward collar would then have a choice of docking at the side units or the lower unit.

As for the need for a third Soyuz-TM craft, I find it hard to believe that the Soviets would not exploit this possibility. They will of course expand Mir's crew complement very soon with the addition of the new shuttle in the 1988/9 time frame if present predictions are correct.

LEE CALDWELL
Toronto, Canada

CORRESPONDENCE

Spaceflight

Sir, I would like to say what a fantastic job you do with ***Spaceflight***, especially the articles on American and Soviet orbital platforms. These I follow with great interest.

PHILIP BARRETT
Plymouth, Devon UK

A Point in Time

Sir, May I make a correction of a point of detail in the caption to the picture of Buzz Aldrin deploying the scientific experiments package on the lunar surface during the Apollo 11 mission (***Spaceflight***, February 1988, p.52)? The date was not July 20 but July 21, 1969.

Lift-off was at 09.32 EDT on July 16. Aldrin made the first move to open the Scientific Equipment Bay (SEQ) containing the experiments at 04.14.52.01 elapsed time (information from the official voice transcript) which means that a photograph by Armstrong of Aldrin depolying the elements of the package must have been after 00.24 on July 21 EDT. Of course, in terms of British time it was July 21 before the Apollo 11 LM hatch was even open prior to Armstrong's egress.

The frame number of the picture incidentally is AS11-40-5949.

H.J.P ARNOLD
Managing Director
Space Frontiers

Space Law

Sir, Since the last Colloquium on the Law of Outer Space in England was held at Lincoln's Inn in 1959, it was good to see this event (the 30th) again in this country as part of the IAF Brighton Congress last October.

The meetings were well attended and the four sessions covered the topics of the Peaceful Uses of Outer Space, Environmental Problems in Space (including debris), Legal Aspects of the Commercialisation of Space, and Legal Principles relating to Remote Sensing.

A lively debate centred on the "broad" and "narrow" interpretations of the Anti-Ballistic Missile Treaty of 1972 when considered in relation to the SDI project, the Soviet delegate, V.S. Vereschetin, not unnaturally challenging the broader interpretation allegedly favoured by President Reagan about how far development and testing of the equipment may be permitted without violating the terms of the treaty.

Commercialisation of space activities was also a topic of new legal interest, particularly with regard to the provision of launch services by private contractors following the various launch failures in 1986 and relations with governments as clients.

The dangers and legal responsibilities of space debris were also discussed, when it was revealed that there are now 6000 tracked objects in orbit, with possibly many more smaller bits.

A paper on the extent to which the various international legal conventions now apply to space activities caused one to observe how the field of activity is broadening in the medium of space, both on the Soviet and Western side, now that new technology and a markedly freer and more open attitude to commercial and private activities in space is becoming apparent. It is important that proper legal control should not be far behind. A lot, of course, will depend upon funding and the state of US/Soviet relations generally, though one speaker felt that even in times of relatively bad relations on Earth between the Super Powers some cooperation might still continue, while another from the United States urged a joint US/Soviet mission to Mars as an alternative to SDI!

C. HORSFORD
London, England

Pluto and the Tenth Planet

Sir, I would like to add to your correspondence on the possibility of a tenth planet (***Spaceflight***, January 1988, p.28). It has been a puzzle to a lot of people as to why Percival Lowell successfully predicted the planet Pluto when it is now accepted that this body is too small to cause perturbations in the orbits of Neptune and Uranus. Over the past few years I have obtained some of the historical papers on this subject in an effort to find the answer to this. The answers I found may seem incredible to many people but I will list my references at the end of this letter so that others may make up their own minds.

Percival Lowell's *Memoir on a Trans-Neptunian Planet* is a slim A4-sized volume of about 100 pages of text and tables with nine graphs. I do not claim to understand its contents but what I discovered from it as soon as I had a copy was that Lowell only used residuals in the position of Uranus of which data existed for some 200 years. What was also clear was that he was using the discrepancies left over from the triumphant discovery of Neptune by LeVerrier and Adams. I have read a number of times that Lowell used discrepancies in the positions of Uranus and Neptune. This illustrates how badly researched popular comment has contaminated this subject.

Though I could not find an answer to Lowell's success from his *Memoir* I was lucky to come across a paper which summerised the investigations of a Frenchman, Dr. V. Kourganoff, whose doctoral thesis was an analysis of Lowell's work – Clyde Tombaugh had mentioned this name in his book *Out of the Darkness*.

The essence of Kourganoff's findings was that Lowell had calculated an eccentric orbit for his Planet X which had a close Uranus approach in the first half of the eighteenth century. Pluto did indeed have a close approach at this time – in fact it went inside Neptune's orbit in doing so, something Lowell could not have anticipated. Kourganoff found the mass required of Pluto to account for the residuals of Uranus reduced from Lowell's seven Earth masses to about one,

There are many other fascinating points to this story but I think the above should start to make most reasonable people want to question the validity of the Plutonian moon which has led to a low inferred mass of this planet. My guess is that a large dark body with patches of methane ice might account for the photographs showing a moon. Iapetus, a moon of Saturn, shows something similar. Moreover, I was happy to read recently that IRAS observations of Pluto showed an infra-red excess.

Kourganoff's work was dated 1940 and the summary I found by Gibson Reaves was published in 1951. At both these times world attention was diverted by war. Perhaps this explains how the truth about Pluto may have been affected. Whatever the possibilities are for a tenth planet I feel that the true facts about Pluto must be known first. I am convinced that Percival Lowell's work was a major piece of scientific scholarship which has yet to be valued for its true worth.

P.W. SCHIMMON
Crawley, W. Sussex.

References

1 Memoir on a Trans-Neptunian Planet, Percival Lowell, 1915
2 Kourganoff's Contributions to the History of the Discovery of Pluto, Gibson Reaves, P A.S P, 63, April 1951
3. The Discovery of Neptune, Morton Grosser, Dover pubs., 1979
4. Out of The Darkness, Tombaugh and Moore, 1980
5. On a Criterion for the Prediction of an Unknown Planet, E.W Brown, M N R.A.S, 91, p.80, 1931

EUROPEAN RENDEZVOUS

Spend More or Quit – report warns Britain

A major report on British space policy has warned that the country must increase its funding or pull out of space activities altogether.

The stark choice is highlighted in a report by the House of Lords Select Committee on Science and Technology which is due to be debated by the Lords at the end of this month (March).

It calls for the Government to increase its £112 million a year space budget to £200 million over the next five years.

The committee, chaired by Lord Shackleton, received evidence from 200 witnesses in industry, education, government and other organisations, including the British Interplanetary Society (see p.118). It concluded that the current level of spending "gets the worst of all worlds".

The report criticises the Government for keeping secret details of the national space plan, prepared by Roy Gibson while he was head of the British National Space Centre (BNSC).

The committee is convinced that the Government, with its stated intention of keeping the space budget fixed at about £112 million, has got the level wrong.

This level of spending gets the worst of all worlds – too much for real savings, too little for lasting achievements. If the budget is to stay at this figure, the UK might as well bow out of space now," says the report.

Existing commitments to ESA cost about £80 million per annum and, according to the committee, the UK national space budget should add to these the polar platform with the UK as prime contractor, a contribution to Ariane 5 and preparations for ERS-2. The cost of the Data Relay Satellite should largely be covered by the tailing off of existing commitments.

"The additional cost of these items would be up to £50 million, taking spending through ESA to around £130 million per annum after five years. This expenditure would reintroduce some flexibility in relation to ESA's programme, which has been lost as a result of all UK funds being committed for some time ahead," says the report.

"A national and bilateral programme of at least half ESA spending would thus cost £60-£70 million, funding existing commitments and such items as data processing capacity for ERS-1, participation in Radarsat and investment in the infrastructure and technology of space programmes.

"Over five years the budget would therefore rise to around £200 million and of this the private sector could be expected to contribute slightly more than the current £20-25 million a year."

The report also sets out the following broad objectives for UK space policy:

1. To give the UK a viable and effective part in the exploration and exploitation of space.
2. To achieve a strong European presence in space (including European autonomous capability in some but not all areas of space activity), while keeping open the option of UK collaboration with other nations.
3. To develop sufficient national competence in space science and technology for the UK to complete internationally and to derive full benefit from international programmes.
4. To give priority to space activities which offer significant scientific or economic benefits for the UK.
5. To exploit advances in space technologies for defence purposes within the NATO alliance.
6. To develop a capability in communications and Earth observation for both civil and defence purposes.
7. To ensure that the interests of users are fully taken into account in decisions about space policy.
8. To increase public and commercial awareness of the opportunities opened up by innovation in the space field.

The report, stating that achievement of such objectives requires a strong BNSC with its own resources, says the Government's current position leads to fundamental questions about the future of the BNSC.

"The committee consider that BNSC cannot be left exactly as it is. One choice, that of abolition, has to be rejected because it would convey the dramatic signal that the United Kingdom was withdrawing from space. Instead BNSC has to be made stronger. It needs the stature and confidence to draw up a space plan acceptable to Government; to talk to industry about the contribution which industry ought to be making to space; and to publicise space in the community and in schools."

The following is a summary of some of the report's main conclusions and recommendations:

The case for space

The case for space is not only one of science and technology, it is political, cultural, economic and military as well. The committee recommend that the UK play a visible and effective part in the exploration and exploitation of space.

National and international programmes

The UK, which should remain within ESA and work for more effective and less costly ESA programmes, spends too little on national space programmes compared with expenditure through ESA. This balance must be adjusted to get better value for money. Satellite programmes with commercial potential should be moved outside the ESA framework.

Also, bilateral collaboration in space should be developed, including defence cooperation with the US and collaboration with the Canadians on Radarsat.

A national space plan

The Government's silence over BNSC's space plan was misleading and contributed to the atmosphere of damaging uncertainty during 1987. The UK now needs a clear policy for space which is adhered to firmly and consistently. The Government should formulate a positive space policy and make a full statement of that policy. This should be supported by a national space plan which should be published and updated regularly.

BNSC

BNSC should be made stronger, preferably by becoming free-standing within Whitehall, with its own Vote. BNSC should answer to a Minister in the Department of Trade and Industry and industrial partners should be brought into BNSC. The next director general might come from industry.

ESA's long-term plan

The UK should play a more constructive role in ESA in the future and be prepared to take part in some ESA projects about which it has reservations, in the interests of full collaboration.

Man in space

For the foreseeable future space offers enough opportunity to telecontrolled craft for the involvement of man in space to be an expensive and hazardous diversion. It is not necessary to put a European in space independently of the Americans. The Government should argue for the modification of ESA's declared pursuit of European autonomy in space.

Space station and Columbus

Given that the Americans are going to build a space station, Europe is right to participate. British participation should be confined to the Advanced Pressurised Module and, subject to certain qualifications, the polar platform. If the Americans, for whatever reason, see advantage in delaying their space station programme, the UK should urge them to do so. Appropriate steps must be taken in the ground sector to prepare for the data generated by the polar platform or by an alternative system of interacting smaller satellites.

Hermes and Ariane

The UK should play no part in Hermes. The committee oppose the man-rating of Ariane 5. Nevertheless, the UK should keep a foothold in launcher development by supporting Ariane 5, even if man-rated, at the same level of funding as Ariane 4.

Launchers

The UK must have access to a reliable low-cost launch system for satellites. International competition should supply this market. In the longer-term the prospects of Hotol should be explored, as an international venture. If at the end of the proof of concept stage of Hotol the future looks promising, the committee favour pressing ahead, subject to certain conditions.

ESA's Ambitious Plans in Space Science

by Norman Longdon

ESA's general objectives in space science were carefully laid down after a full and comprehensive discussion with the leaders of the European space science community in the mid-1980's. Known as 'Space Science: Horizon 2000', the long-term plan has since been updated and aims at maintaining Europe in the forefront of scientific progress.

The main objectives are to:

- Contribute to the advancement of fundamental scientific knowledge.
- Establish Europe as a major participant in the worldwide development of space science.
- Offer a balanced distribution of opportunities for frontline research to the European scientific community.
- Provide major technological challenges for innovative industrial developments.

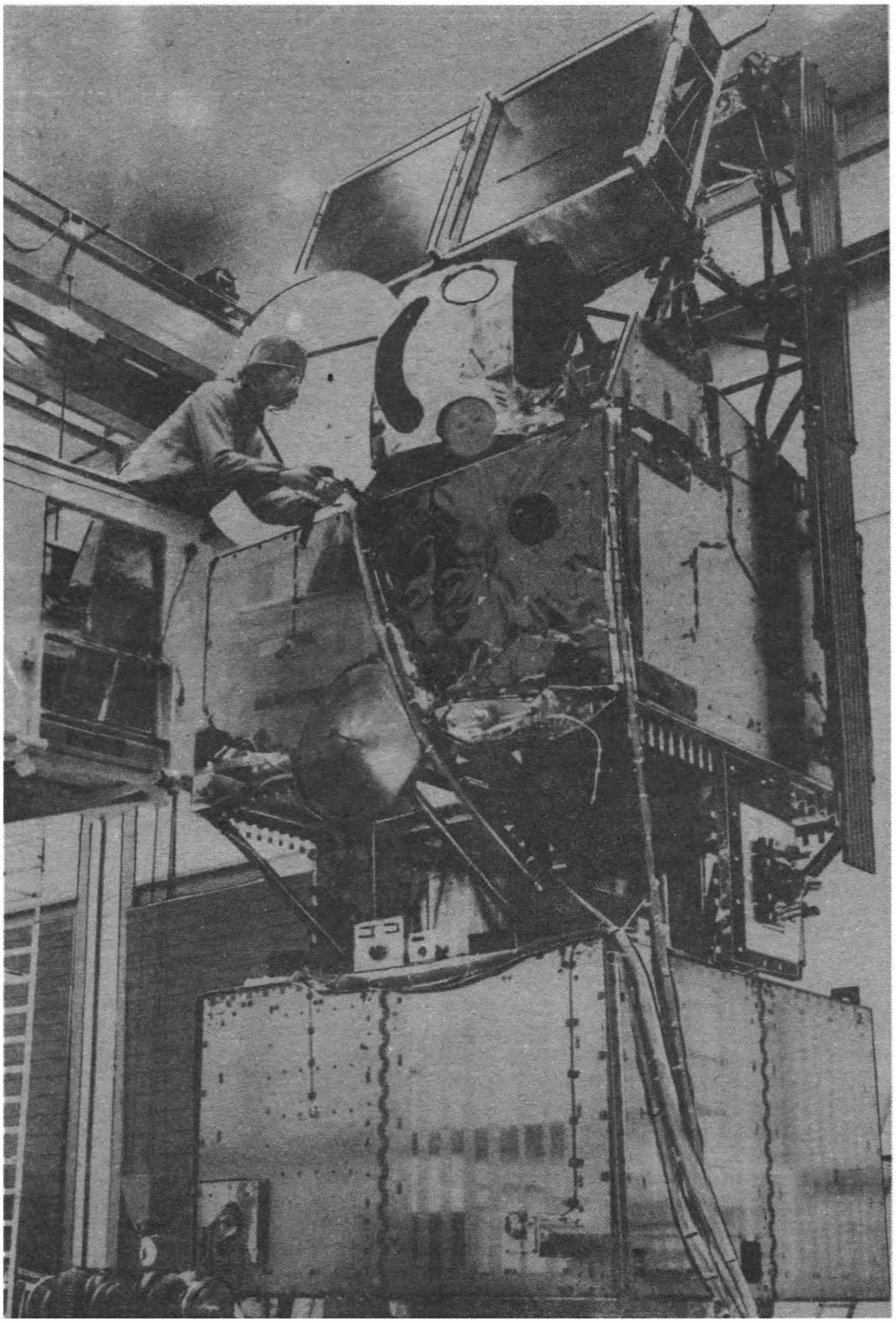
Programme Elements

ESA's future scientific programme must be autonomous, though complementary to the space science programmes of other agencies. A well-balanced sequence of large-and medium/small-sized projects in all of the classical space science disciplines is needed to ensure continuity of effort both in Europe's scientific institutes and in industry. This is the only way for the mandatory programme to ensure a balanced industrial return to the member states. There must also be room for desirable cooperative projects with other agencies, although these should not become preponderant.

The Horizon 2000 plan rests on four major 'cornerstones', which are:

1. The Solar-Terrestrial Science Programme (STSP), composed of two medium-sized missions. The implementation of the STP cornerstone, a cooperative undertaking by ESA and NASA, now consists of two space missions: Soho, the Solar and Heliospheric Observatory, and Cluster, a four spacecraft space-plasma-physics mission. The prime objective of the STSP is to attack outstanding scientific problems in solar, heliospheric and space-plasma physics through a unified and coordinated approach.

Part 1 of this article, 'Europe Takes Aim – the 21st Century in its Sights', appeared in **Spaceflight**, *January 1988, p.34.*



ERS-1 being prepared for vibration tests. This will be the agency's first remote sensing satellite and launch is currently scheduled for early 1990. *ESA*

As a multi-disciplinary solar observatory, Soho and Cluster will address the major issues of the Sun-Earth relationships. Current plans are for Soho to be launched in 1994 into a halo orbit around the L_1 Lagrangian point, about 1.5 million kilometres sunward from the Earth. It will observe the Sun, its corona and the solar wind continuously by remote-sensing as well as in-situ techniques.

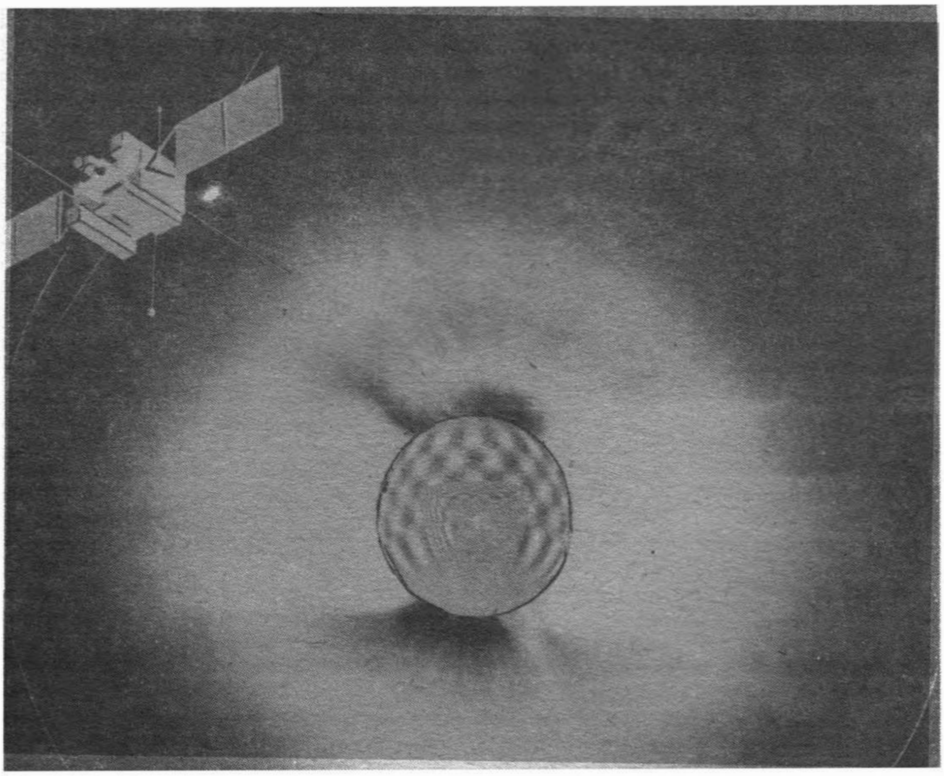
The Cluster mission, to be launched into polar orbit by an Ariane 5 test flight in 1995, will study the reactions of the

Soho to Monitor

The multi-faceted Solar and Heliospheric Observatory (Soho) will address itself to answering three fundamental questions: the structure and dynamics of the Sun's interior; why does the solar corona exist and how is it heated; and, where and how is the solar-wind accelerated, *writes Aldo G. Rabaiotti.*

By studying the Sun's internal structures, especially temperature, pressure and dynamics through observations of coronal oscillations, scientists will be able to build up a picture of how the Sun operates.

The second and third questions are closely related and involve the study of the processes that operate within and without the solar atmosphere. The solar corona – seen as a halo of pearly white gas during an eclipse – is responsible for generating the solar wind, an invisible, superheated, high-velocity gas or plasma that spills out to touch every point of the Solar System. Just as the solar corona is irregular in shape and spasmodic in its behaviour, so too is the solar wind.



Artist's impression of the Soho spacecraft in orbit around the Sun. ESA

magnetospheric space plasma to the varying solar conditions. It will investigate in detail the physical processes that occur in key regions of geospace.

The joint ESA/NASA Announcement of Opportunity for scientific investigations on Cluster and Soho was released in March 1987; and more than 500 scientists from all over the world are involved in the proposals submitted.

2. A planetary cornerstone composed of a major project to visit primitive bodies of the Solar System and to return pristine material.

This has now been further defined as a mission to a comet with the return of nucleus material. A Comet-Nucleus Sample-Return Mission (CNSR) constitutes the next logical step in cometary exploration after flyby (Giotto) and rendezvous (CRAF) missions. It has been studied as a collaborative mission by a joint ESA/NASA Science Definition Team and studies are currently underway to develop technologically feasible CNSR mission profiles. These studies include various propulsion systems, such as chemical and solar electric propulsion as well as hybrid systems.

Joint definition of mission options and discussions on the sharing of responsibilities between ESA and NASA are currently under way. The baseline mission aims for a launch around the year 2000 and return of the samples after a total mission duration of six to eight years. Such a mission may make use of the space station as a staging facility and for the analysis and storage of the samples.

3. An X-ray astronomy cornerstone composed of a major project aimed at studying X-ray sources with good spectral resolution.

The high-throughput X-ray spectroscopy cornerstone is aimed at making a major step forward in astrophysics in the mid-1990's. The scientific objectives require a powerful imaging instrument, with the largest possible collecting area, for high-quality spectral measurements on faint sources.

... a major project to visit a comet and return pristine material.

Definition of this cornerstone has evolved very significantly since it was initiated in 1986 and this mission, presently called the X-ray Multi-mirror Mission (XMM), to be launched in the late 90's, would be a natural follow-on to the highly successful Exosat mission. It would provide the European scientific community with continuity of research and a major X-ray facility in a time frame consistent with NASA's AXAF project, with which cross-coordination would be of the utmost scientific value. The mission is now undergoing extensive analysis, both in ESA and in industry.

4. A submillimetre astronomy cornerstone composed of a large telescope for studies of the physical characteristics of infrared sources by means of heterodyne detectors.

Four areas of astrophysics have been identified that require progress in the techniques of submillimetre observations:

- The physics of the interstellar medium and its fragmentation into proto-stellar clumps.
- The physics of star formation.
- Cosmological studies.
- Properties of primitive Solar System material through studies of comets.

A mission that would satisfy most of these needs, the Far-Infrared and Submillimetre Space Telescope (FIRST), was the subject of an assessment study in 1983. It would provide access to the last unexplored band of the space-observable electromagnetic spectrum. Preparatory work on the mission is still in progress, but the technology which needs to be developed has already been defined and industrial study contracts have been awarded. This mission would, in fact, build on the development experience gained with ESA's ISO mission.

Two mission options are still under investigation, one of them making this cornerstone space station 'serviceable'.

In addition to these four cor-

Sun Activity

The spacecraft will use spectrographic equipment to investigate the solar plasma, with emphasis given to collecting data on plasma density, velocity, temperature and magnetic fields. From this data will be constructed computer 'models' to highlight plasma heating, solar-wind acceleration and the mechanism in which mass, momentum and energy is taken from the photosphere to the corona. This will be complemented by contour-mapping and coronaography, which will show the smaller structures of the inner-corona, the larger structures of the outer-corona and the solar wind.

Scientists have speculated that the solar wind may emanate from specific points on the corona that may, or may not, change position and extent. Soho will provide in-situ measurements, over many months and with great accuracy, allowing scientists to establish whether the solar wind is an overall phenomenon or one confined to certain regions in the corona.

nerstones which form the basis for European space science activities for the remainder of the century, a number of medium and smaller sized (i.e. less costly) projects will also be carried out. Among these are several selected some years ago, two of which – Ulysses and the Hubble Space Telescope – are awaiting launch after the resumption of NASA space shuttle flights. Two other spacecraft – Hipparcos and ISO – are now under development and are due to be launched in 1989 and 1993, respectively.

A further four or five new projects will be selected over the coming years, thereby ensuring that the overall programme retains the degree of flexibility needed to enable it to meet the developing needs of the scientific community.

All these elements are in the more traditional space science disciplines, which form part of the mandatory programme of the Agency, and as such the funding of the space science programme must be agreed unanimously by the member states. All the countries, except the United Kingdom, have indicated their belief that a modest increase in funding is necessary beyond 1989 to retain this exciting and rewarding programme. It is hoped that the United Kingdom will reconsider its position before the budgets for the early 1990's are decided.

Other basic research activities such as geodesy, climatology, and microgravity research, are also being pursued. These applications-related activities are being carried out via ESA's optional programmes.

Role of the Space Station

An element of flexibility in the scientific programme is the provision of a number of smaller projects. These respond to the need for frequent flight opportunities and will allow ESA to react quickly to support the study of new, unexpected phenomena. In this context, the capabilities that are expected to be offered by the Columbus/space station programme could be very relevant.

Earth Observation Programme

Over the past 15 years Europe has made a significant contribution to Earth observation from space. Since 1977 the Meteosat satellites have provided data for both weather prediction and scientific research and the success of this programme led to the establishment of a new organisation–Eumetsat, which represents the European Meteorological Services and which is now responsible for the future Meteorological Operational Programme (with three satellites to be launched in 1988, 1990 and 1991). ESA continues its involvement by procuring the satellites together with the associated ground control centre.

The ERS-1 satellite with its unique set of all-weather microwave instruments will address, as from early 1990, coastal, ocean and ice processes for both scientific research and applications.

Experience shows that there is no distinct borderline between science and applications in Earth observation.

The Earthnet programme manages and operates a network of ground stations and associated facilities for receiving, preprocessing, archiving and dissemination data from Earth observation satellites. It will expand the data from the ERS-1 satellite.

The newly set up Earth Observation Preparatory Programme (EOPP) will pave the way for the new programmes running in the 1990's.

Experience shows that there is no distinct borderline between science and applications in Earth observation since operational and/or economic exploitation of remote/ sensing data can only result from a deep understanding of the physical mechanisms that underline the various observed phenomena on the surface of the Earth, in the oceans and in the atmosphere. In most cases the distinction between science and applications only reflects the stage of maturity achieved in the various individual disciplines.

European Remote Sensing

After discussions with the potential user communities the objectives set are:

- To establish, by the mid 1990s, operational systems in polar orbit for scientific and applications needs in the fields of ocean, ice, coastal processes and meteorology.
- To develop a polar orbit space segment for experimental/pre-operational use for land applications, with emphasis on all-weather microwave instrumentation.
- To develop a second-generation meteorological satellite to be launched around 1995 to ensure continuation of the Meteosat operational system.
- To provide research tools for scientific studies in the fields of solid Earth, climatology etc.
- To prepare potential future missions by advanced system and instrument studies and carry out pre-development of such instruments.
- To develop further the ground segment, currently based on Earthnet facilities for payload data handling.

In order to achieve these objectives, the following programmes have been proposed, most of which originate from the Earth Observation Preparatory Programme (EOPP).

ERS-2, to follow ERS-1, will:

- Ensure the continuity of operation started by ERS-1.
- Monitor coastal zones, global ocean processes and polar ice regions, thus making a major contribution to the World Climate Research Programme.
- Develop and exploit the coastal, ocean and ice applications of remote sensing data (industrial activities to benefit most from expected meteorological forecasting improvements and accurate knowledge of ocean and ice geophysical processes include offshore oil prospecting, ship routing and fishing activities).
- Develop scientific research and application demonstration activities using all-weather high-resolution data from the imaging radar (SAR).

Currently the launch date is planned for 1993, and the satellite would have a lifetime of five to six years.

A second-generation Meteosat, with a launch date of 1995, is needed to:

- Fulfil the increasing demands for meteorological applications such as short-period weather forecasting.
- Provide data on atmospheric pro-

files of temperature and water-vapour content, which would strenghten weather-forecasting numerical models.

- Disseminate a larger amount of data as quickly as possible.
- Make a new contribution to both meteorology and the World Climate Research Programme.

Polar Orbit Earth-Observation

This programme, with an expected launch in 1997, would:

- Expand the scientific and application objectives in ocean and ice initiated by ERS-1 (e.g ocean colour, sea-surface temperature).
- Provide a continuous atmospheric-monitoring service for scientific, operational and climatological purposes.
- Demonstrate the scientific capabilities of new sensors for advanced land applications (e.g. agriculture, forestry, hydrology and geology).
- Provide a scientific contribution to the study of middle and upper atmospheric processes.

Solid Earth

This programme element would contribute to the understanding of the physical forces and processes which are active in the interior of the Earth and responsible for catastrophic events on the Earth's surface.

Two distinct types of measurements could be made: determination and mapping of geopotential fields (gravity and magnetic fields) using a low-orbit spacecraft (160-200 km altitude); and, precise point positioning (to centimetre accuracy) using a high-orbit spacecraft (7000 km altitude).

ESA is presently studying a geopotential mission to be carried out from a low-orbit satellite ('Aristoteles') equipped with a gravity gradiometer and possibly including magnetic-field measurements. This mission has been given priority by the scientific community and would involve a dual launch with ERS-2.

'Passenger' Payloads

These will be sought to develop and test advanced instruments in orbit through various flight opportunities and provide flight opportunities for nationally developed instruments. In both cases the space station and its elements such as the Columbus Polar Platform could be used.

Preparatory Activities

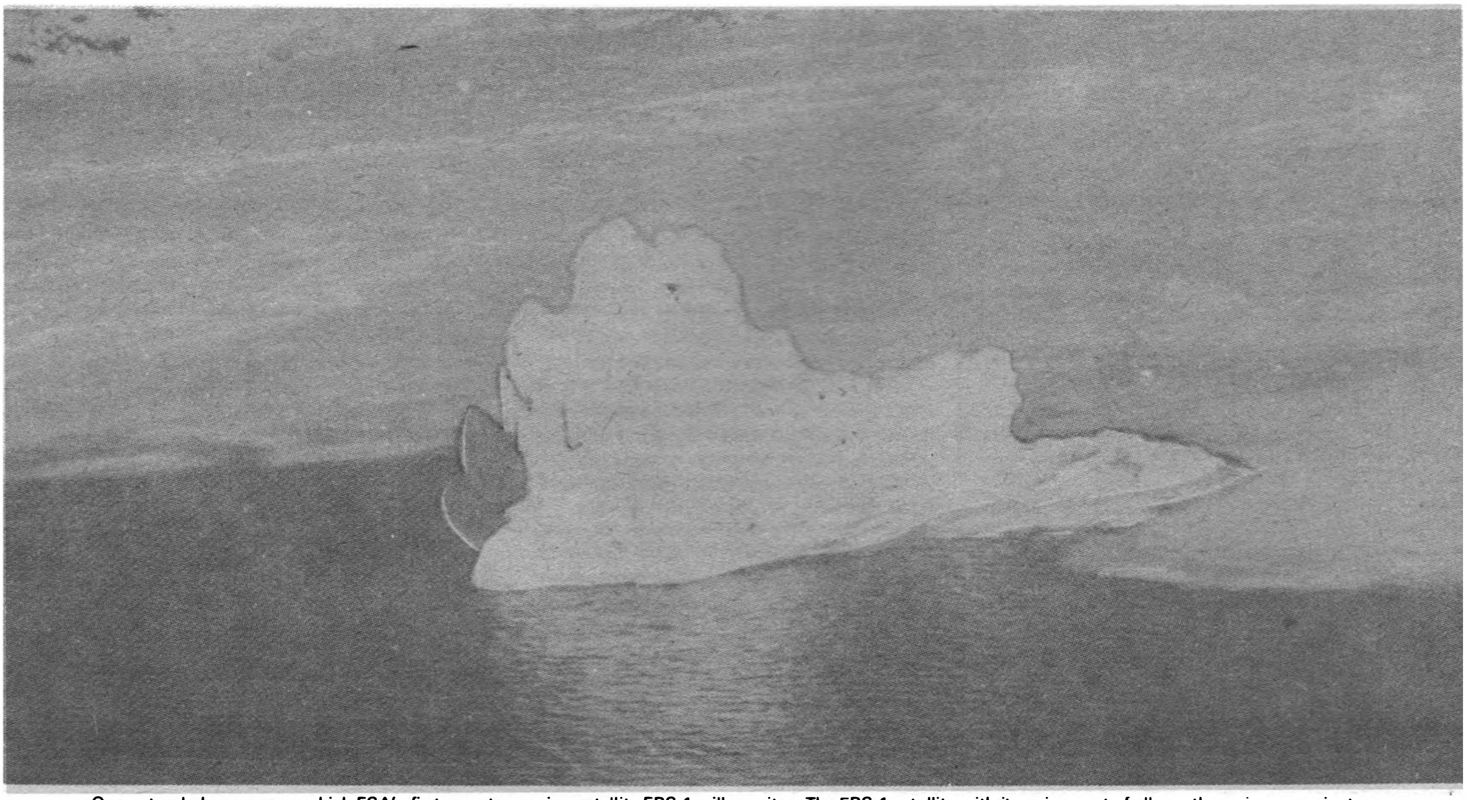
Under the Earth Observation Preparatory Programme (EOPP) a number of activities are being carried out: advanced system studies, measurement campaigns, instrument studies, phase-A studies, and technology predevelopments in order to explore different alternatives for candidate future programmes.

Earthnet will be developed further:

- To define, implement and operate the Earth observation payload ground data handling system to fulfil European requirements.
- To ensure acquisition, archiving, cataloguing, preprocessing and disseminating payload data from experimental, preoperational and selected commercial remote-sensing missions developed and operated by ESA or by third parties (e.g. NASA, NOA, EOSAT, CNES, NASDA, ISRO).

Even with just the space science and Earth observation programmes, it is easy to see how ESA's long-term plan seeks to draw many disciplines into the use of space. In some instances the potential in economic or commerical terms can be guaged, although not with any certainty yet: in other ventures the outcome may initially have a pure research element.

However, it is abundantly clear that all the programmes embrace the capability and capacity of European high techological industry with spin-off into many different applications. The long-term gains in knowledge and markets will outweigh short-term considerations.



One natural phenomenon which ESA's first remote sensing satellite ERS-1 will monitor. The ERS-1 satellite with its unique set of all-weather microwave instruments will monitor the formation and movement of icebergs from the early 1990's Increased observations of polar ocean and ice processes in the 1990's will be of economic value to offshore oil prospecting, ship routing and fishing activities *British Antartic Survey*

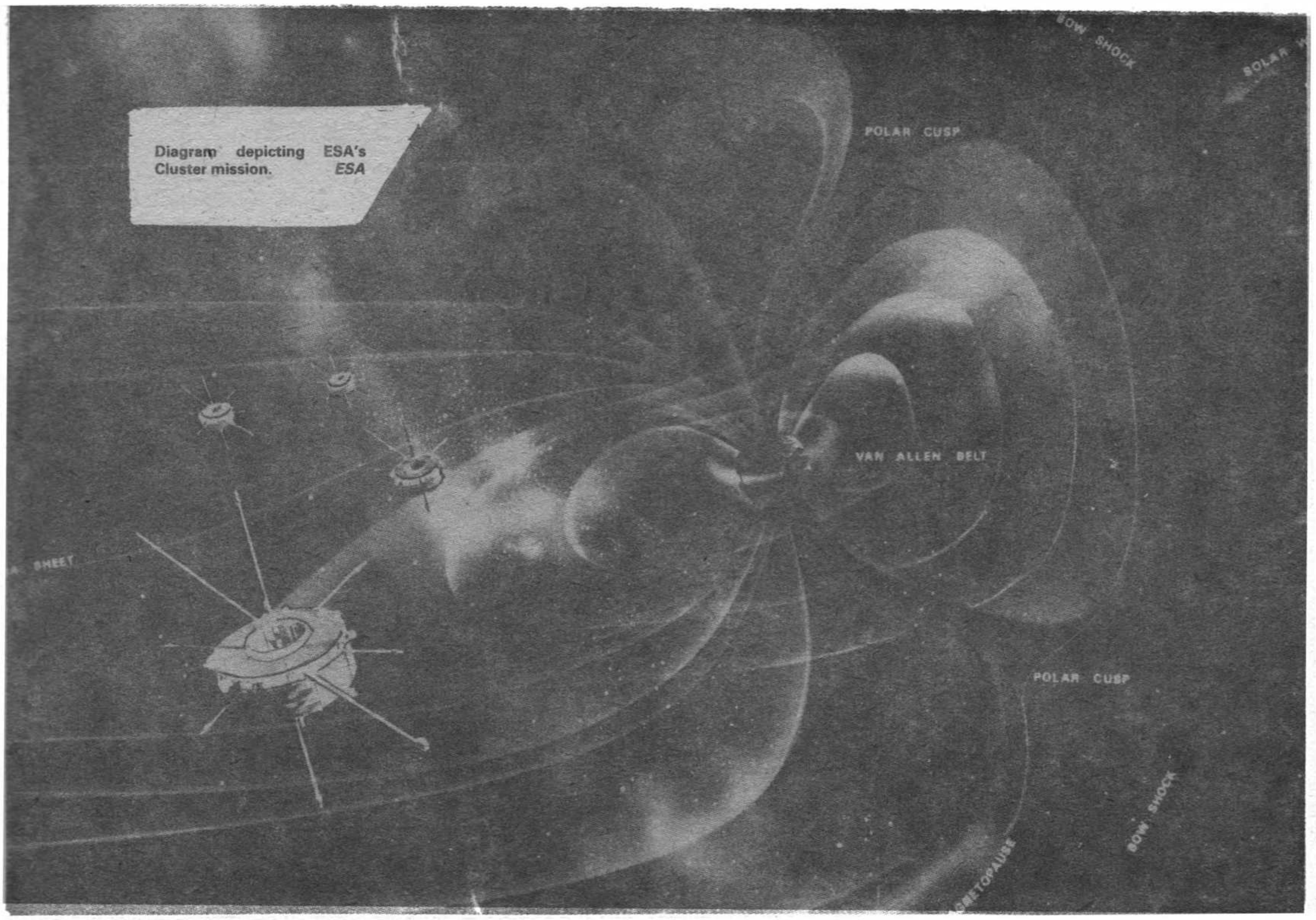
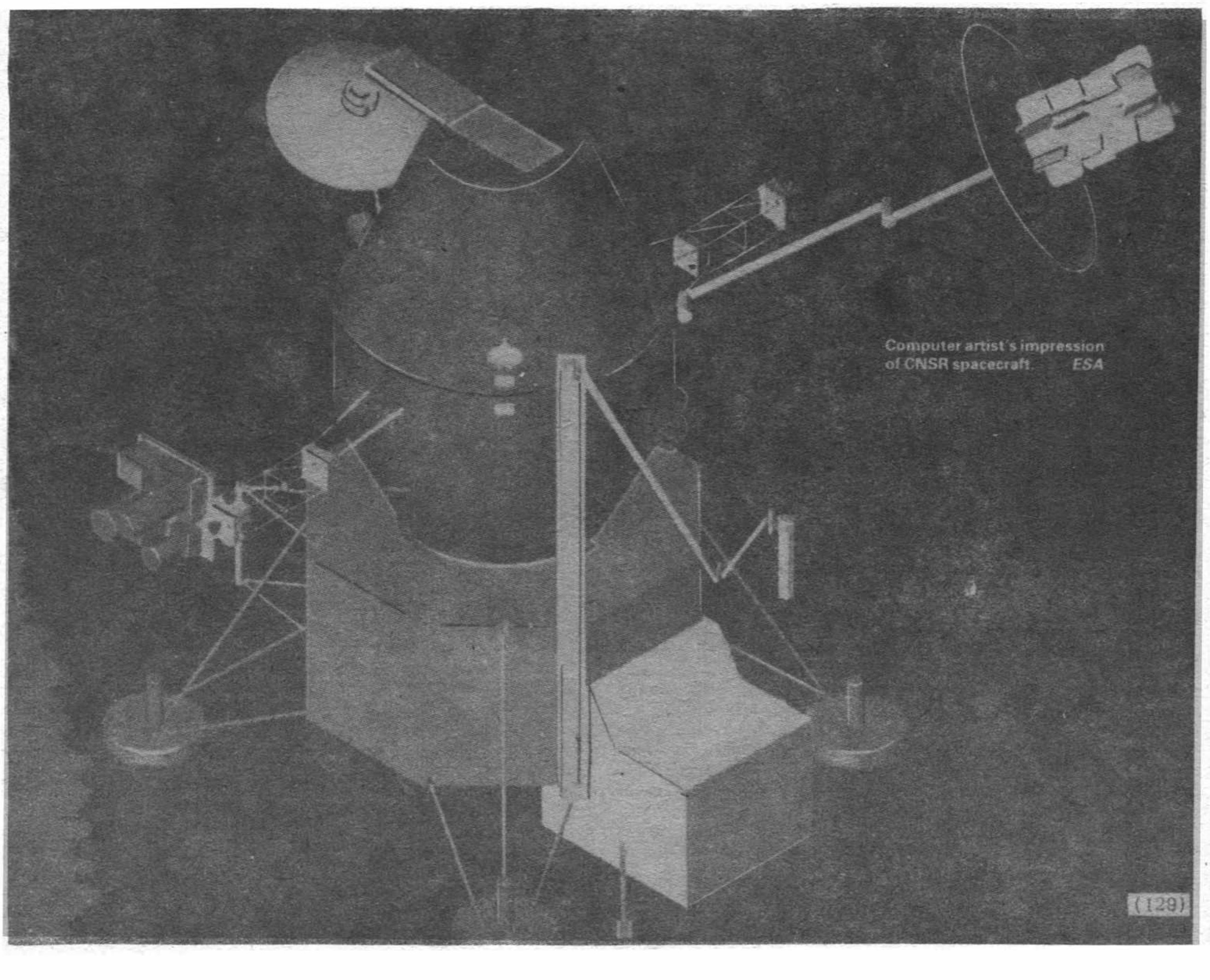


Diagram depicting ESA's Cluster mission. *ESA*



Computer artist's impression of CNSR spacecraft. *ESA*

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Making Space Pay

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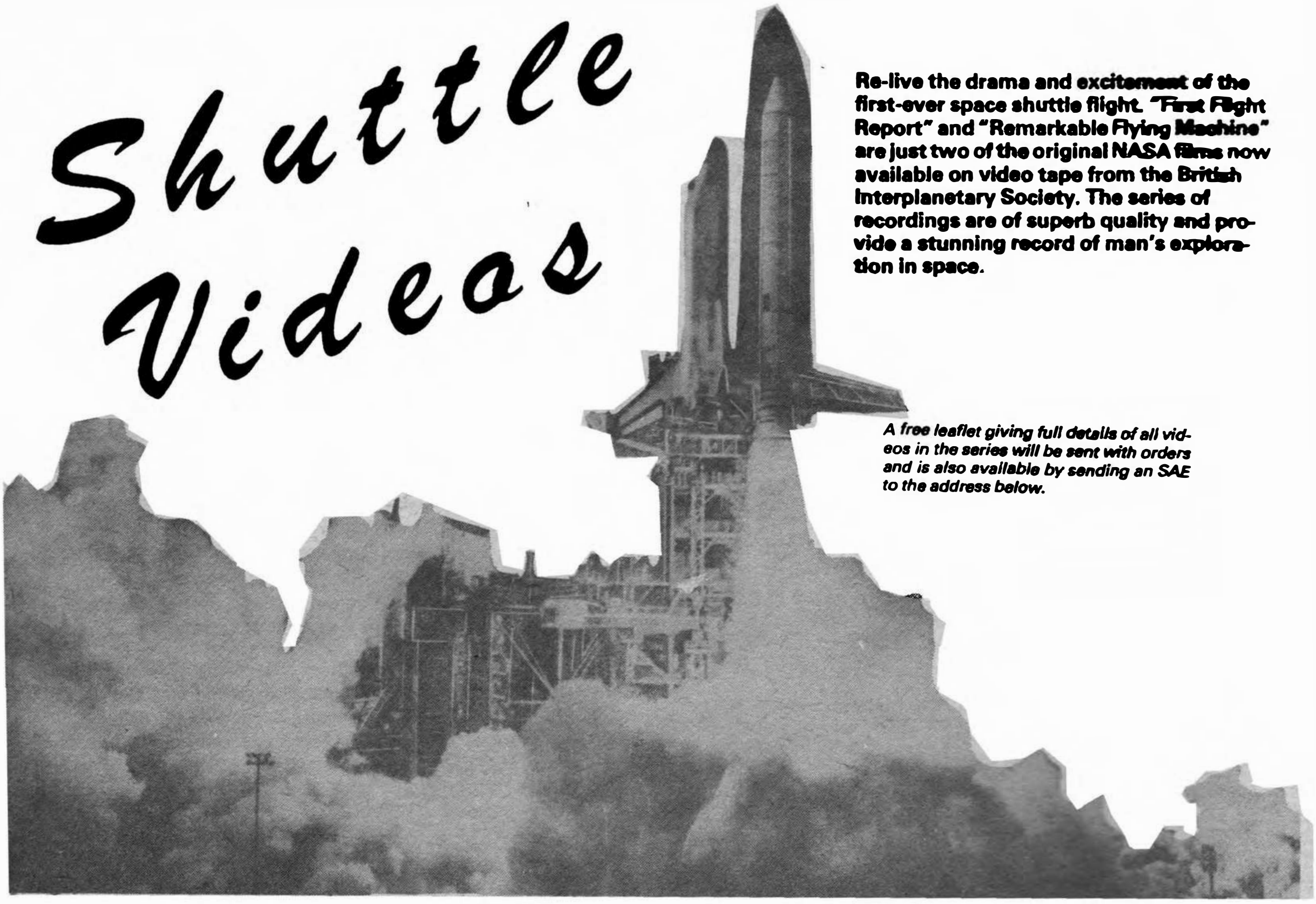
Shuttle Videos



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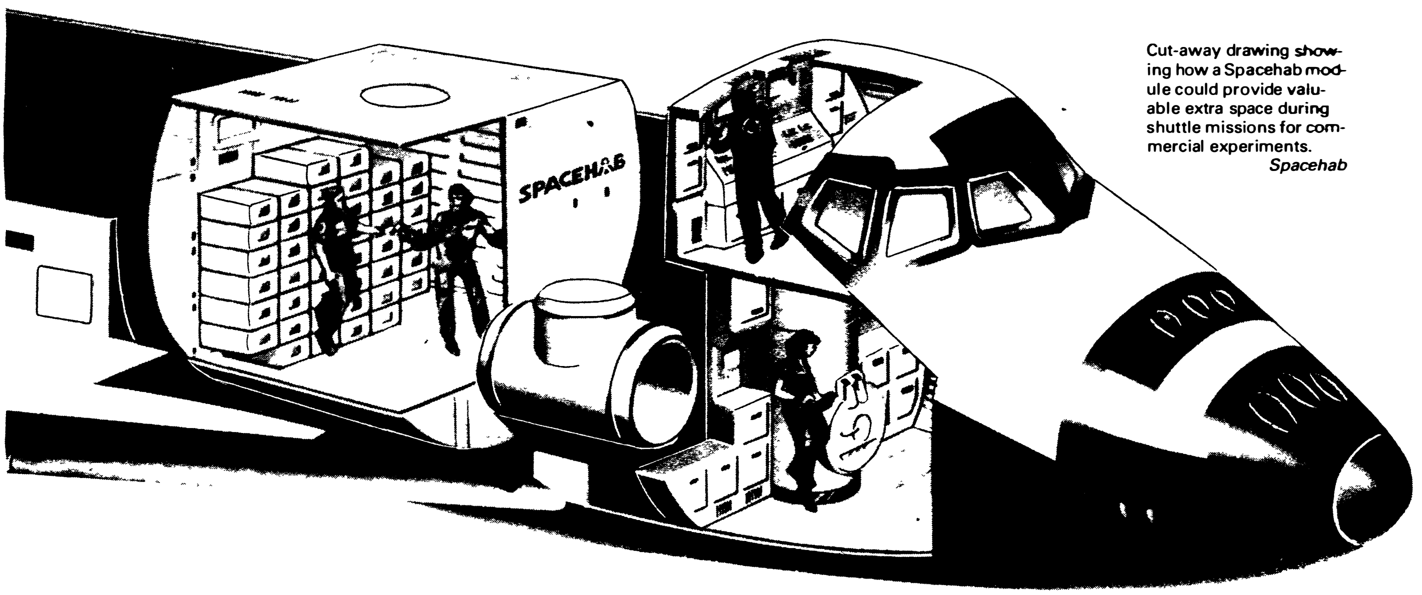
Front Cover: Future and present commercial space activities are highlighted in a number of reports and articles in this issue, beginning with 'Space for Rent' on p.138, which features the commercially developed Spacehab module. One use for such modules will be as extensions to the international space station as pictured on this month's cover. *Spacehab*



Cut-away drawing showing how a Spacehab module could provide valuable extra space during shuttle missions for commercial experiments.
Spacehab

SPACE for RENT

Two private-sector projects could provide important research and commercial manufacturing facilities in space in the early 1990's.

by David Maclennan*

President Reagan's recently announced new space policy for the US (p.154) calls for an orbiting manned space station. The new facilities are to be built, operated and paid for by the private sector. The plan includes the commercially owned and operated space module 'Spacehab', which is to receive government support for its development. In addition, NASA has been given the task of seeking proposals for a still more ambitious facility. One company already has its proposal in hand for an "Industrial Space Facility' (ISF). Both 'Spacehab' and the 'ISF' are modules designed for use in conjunction with the space shuttle.

Spacehab Inc, of Seattle, Washington, is developing the Spacehab module that will be mounted in the US shuttle's cargo bay to provide more experiment space, and Space Industries Inc, of Houston, Texas, is developing the Industrial Space Facility (ISF) that will be serviced at regular intervals by shuttle crews. Both projects will enhance the prospects for the commerical use of space for experimentation and production.

David Maclennan FBIS is vice president of the New Zealand Spaceflight Association

Spacehab

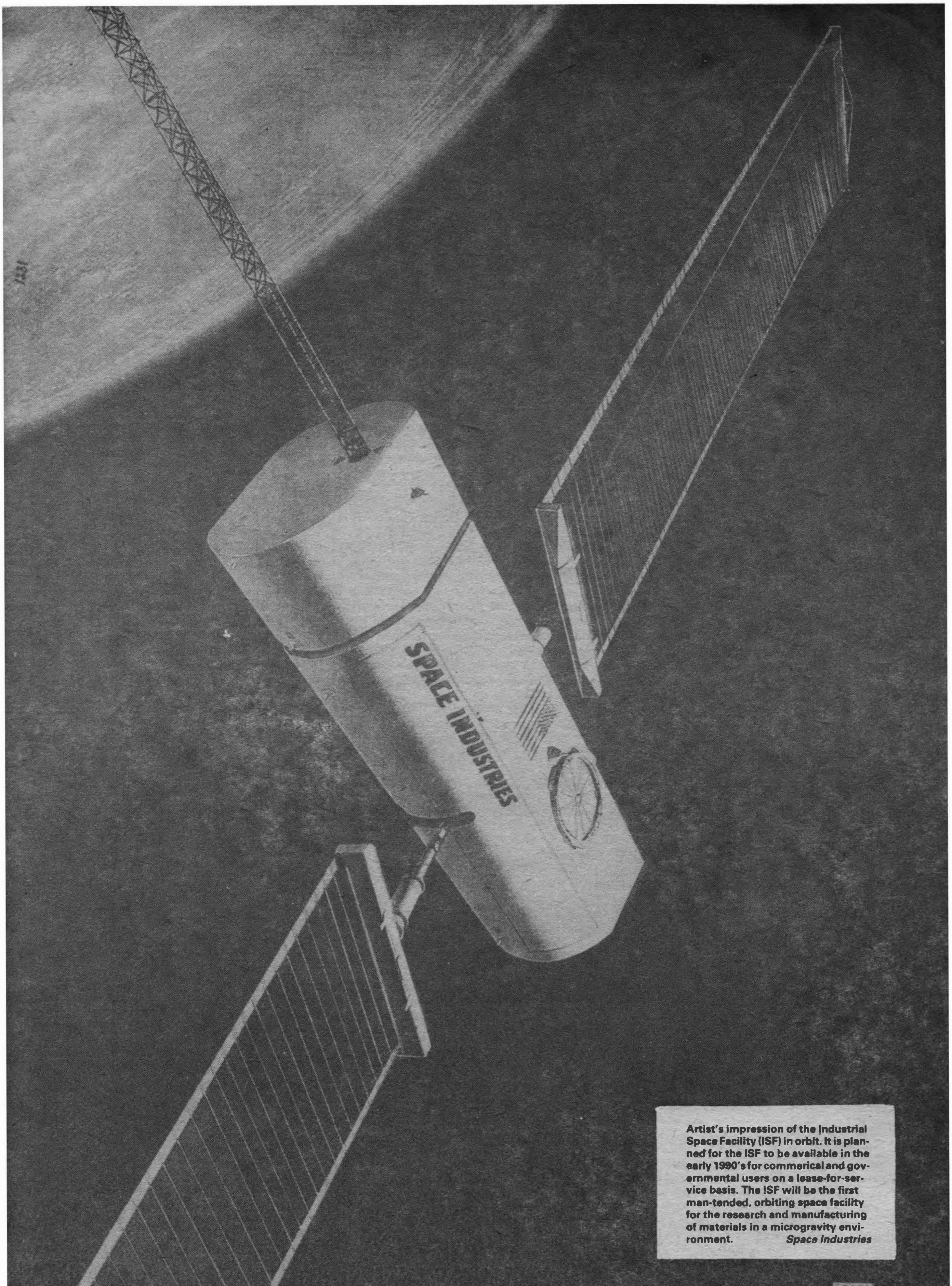
The Spacehab proposal arose out of a shortage of locker space on the shuttle for small, relatively inexpensive experiments. The shuttle middeck area has 42 of these small lockers; all but seven or eight, however, are needed for crew equipment and supplies so even before the Challenger accident there was a long waiting list for experiment space in these lockers.

Spacehab was founded in 1983 by Robert Citron, an experienced space engineer, administrator and consultant (Citron left at the end of 1987 when he formed a new company Space Enterprises Inc). The Spacehab concept is elegant in its simplicity: a cargo bay-mounted pressurised module offering up to 64 additional lockers plus an internal working volume of 28 cubic metres. Spacehab's designers call it a "middeck augmentation module".

Spacehab is mounted at the forward end of the large cargo bay and is entered from the shuttle cabin through a short tunnel. The module measures only 3 m long by 4 m wide, leaving ample space in the 18 m long cargo bay for other payloads.

Unlike ESA's cylindrical Spacelab, Spacehab has a flat "roof", which will provide astronauts on the shuttle flight deck with a clear view over the top of Spacehab to the rest of the cargo bay. The flat roof has other uses too: experiments requiring exposure to the vac-

Continued on p.140.



Artist's impression of the Industrial Space Facility (ISF) in orbit. It is planned for the ISF to be available in the early 1990's for commerical and governmental users on a lease-for-service basis. The ISF will be the first man-tended, orbiting space facility for the research and manufacturing of materials in a microgravity environment. *Space Industries*

uum of space could be mounted there, or an airlock fitted to allow short-term exposure for experiments.

Spacehab claims that its module will significantly enhance the usefulness of the space shuttle, and that it will encourage space commercialisation by providing users with frequent and low-cost crew-tended access to space. Maximum flexibility in interior design is planned to encourage a broad range of customer requirements.

And who will these customers be? Spacehab expects US government agencies, such as NASA and the Department of Defense, will become major users. Other potential customers may come from companies developing space products, universities, research institutions and foreign governments and entrepreneurs.

In designing and building Spacehab, the company has enlisted the help of Italy's Aeritalia and West Germany's MBB-ERNO, both able to draw on experience with Europe's Spacelab. McDonnell Douglas is prime contractor.

Spacehab has also benefitted from the experience of two former shuttle crew members, Owen Garriott and Byron Lichtenberg. Both have been hired as senior consultants on manned space experiment operations and will assist in planning and operations of crew activities and training procedures for Spacehab users. They will advise the engineering team on interior design requirements, experiment command and control, and data management systems.

Initially, three Spacehab modules will be built. The company hopes to fly the first Spacehab in 1991 (***Spaceflight***, December 1987, p.403), increasing to five per year by 1992/93. This may be overly ambitious: any kind of payload space on the shuttle is going to be at a premium for several years following the resumption of flight operations.

Spacehab will not be stopping there, however. Beginning in the early 1990s, the company hopes to have a "mark 2" version available, which it is calling the Space Development Module. These modules are planned as test-beds for the international space station, as well as for space station construction and logistics support.

The Space Development Modules could be used to test equipment and systems for the space station, simulations, and for work in such fields as advanced technology development, artificial intelligence and robotic research, life sciences, and commercial proprietary research and development. Unlike the initial Spacehabs, the Space Development Modules will contain major subsystems for life support, auxiliary power, thermal control and other utilities.

Both the initial Spacehabs and the Space Development Modules will remain attached to the space shuttle at all times. A third Spacehab development, however, could be space station support modules. These super-Spacehabs will be deployable and capable of docking with the space station. They could add to the operational flexibility of the station by providing a very adaptable 28 cubic metre pressurised volume to any space station element. Spacehab foresees up to half a dozen such modules docked to space station nodes by the late 1990s for a variety of commercial, scientific and government purposes.

Industrial Space Facility

Perhaps even more ambitious than Spacehab is the Industrial Space Facility (ISF), being developed by Space Industries Inc.

President of Space Industries and originator of the ISF concept is Dr. Maxime Faget, a well - respected space engineer, having headed the team that designed and developed all four generations of NASA manned spacecraft (Mercury, Gemini, Apollo and Shuttle), until his retirement from the space agency in 1981.

Several other respected former NASA personnel are also key players in the ISF project, including former shuttle astronaut Joe Allen, and Caldwell Johnson, formerly Chief Spacecraft Designer at NASA's Johnson Space Center, who supervised the preliminary design of the space shuttle.

With that depth of experience, Space Industries has been taken very seriously by the space community since its formation in 1982. In 1986 the company formed a partnership with Westinghouse Electric Corporation for the design, development, construction and marketing of the ISF, which will be the first privately-owned, man-tended orbiting space facility for research and manufacturing of materials, systems and technology development, and on-orbit storage. Other major companies involved in the ISF include Boeing and Lockheed.

To get the project off the ground, Space Industries signed a unique "fly now, pay later" agreement with NASA, whereby NASA will provide two and a half dedicated shuttle flights to launch and service the ISF, with payment being made as a percentage of revenue once the facility is operating. This means that Space Industries does not have to raise the large amount of capital needed for a pre-paid launch.

The ISF's fortunes were also enhanced recently by a White House policy group decision directing NASA to lease the ISF as a precursor to its large space station. However, NASA opposes this decision, maintaining that it would take funding away from the space station.

The ISF concept arose out of what was seen as a need for, firstly, a permanent facility in space complete with power and other utilities needed for space-based activities, and secondly, a docking system to allow shuttles to berth with structures in space.

Summer Start for Modules

Construction of the first hardware elements for both Spacehab and the Industrial Space Facility must start this summer if launch targets of the early 1990's are to be met.

Spacehab and Space Industries plan to start work in July but funding arrangements for the two projects are still to be confirmed and both companies are urgently seeking agreements with NASA for shuttle flights.

Expected to be ready by 1991 or 1992, it will comprise of two basic elements. The first is a Facility Module which houses the basic utilities needed for production (electrical power, cooling and temperature control, data handling capabilities, and a pressurised, low-gravity environment) and will remain permanently in space.

Two large solar panels will provide 12 kilowatts of power for users, and four docking ports will be located externally to allow berthing with the shuttle or other ISF modules. The Facility Module will have about 71 cubic metres of interior volume which will be pressurised, allowing astronauts to service or change equipment without having to wear bulky pressure suits.

The other major element is the Supply Module, which will be carried to and from the ISF by the shuttle, for transporting raw materials, re-supply equipment, and – eventually – finished products.

The ISF is designed to be fully operational with a single shuttle launch. On re-supply missions, the shuttle will dock with the ISF, Supply Modules will be exchanged and the crew perform any other tasks required, such as cleaning and maintenance. Once this is completed, the shuttle will depart, leaving the ISF to operate as an autonomous, unmanned free-flyer until the next visit.

As with Spacehab, design flexibility is a key feature of the ISF, allowing ease of maintenance and replacement and updating of parts by using modular systems. Furthermore, two or more complete ISFs could be linked together to form a crew-tended space station.

The docking system under development by Space Industries will probably also be used as a standard element for the shuttle and space station, providing commonality of systems.

The ISF will have many applications and among the products that could be manufactured aboard the facility are: specialised pharmaceutical products for treating diabetes, emphysema, multiple sclerosis and various blood diseases; pure exotic crystals for use in high-speed computers and other advanced electronic devices; and new homogeneous alloys comprised of mixtures of materials that cannot be produced on Earth.

It will have other uses, too. A life sciences laboratory, or an orbiting warehouse for equipment, spare parts and supplies are two examples. The ISF could also serve as a test bed for new technologies and procedures to be used in space. Space Industries believes that the Department of Defense will be a major user, attracted by the ability to attach payloads to the outside of the canister.

Delays in the space station operational date and the shortage of experiment space on shuttle flights will make the Spacehab and ISF concepts attractive to customers anxious to get their research and development projects under way. By the middle of the next century, when space-based industry is commonplace, history may well record Spacehab Inc and Space Industries Inc as the pioneers of commercial space development.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events.

MONTREUX

UK Firm Wins Major ESA Contract

The European Space Agency (ESA) has awarded a major contract to Marconi Space Systems of the UK for development of an advanced L-Band payload for future communications satellites.

The spaceborne radio package, Aramis, will enhance voice and data communications to meet the predicted expansion in satellite communications services to mobile users on aircraft, ships and trucks.

According to details released at Space Commerce '88 held in Montreux at the end of February, the key feature of Aramis is its advanced patch array antenna driven by a network of transmit/receive modules which provide a combination of high gain, fixed and steerable spot beams, as well as a measure of frequency re-use.

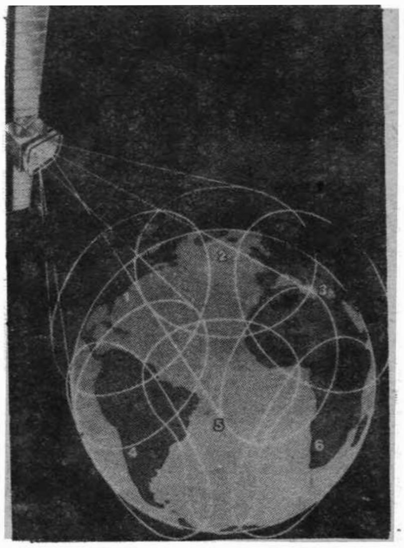
This means satellite power can be focused more effectively and control communications between a larger number of channels. It will also lead to smaller and lower cost mobile Earth stations.

Aramis is seen as an important space element in ESA's plans to pioneer and stimulate the mobile services of the future: public telephone and improved air traffic control for aircraft; and telephone, paging and navigation services for trucks, small ships and pleasure craft (***Spaceflight***, November 1987, p.363).

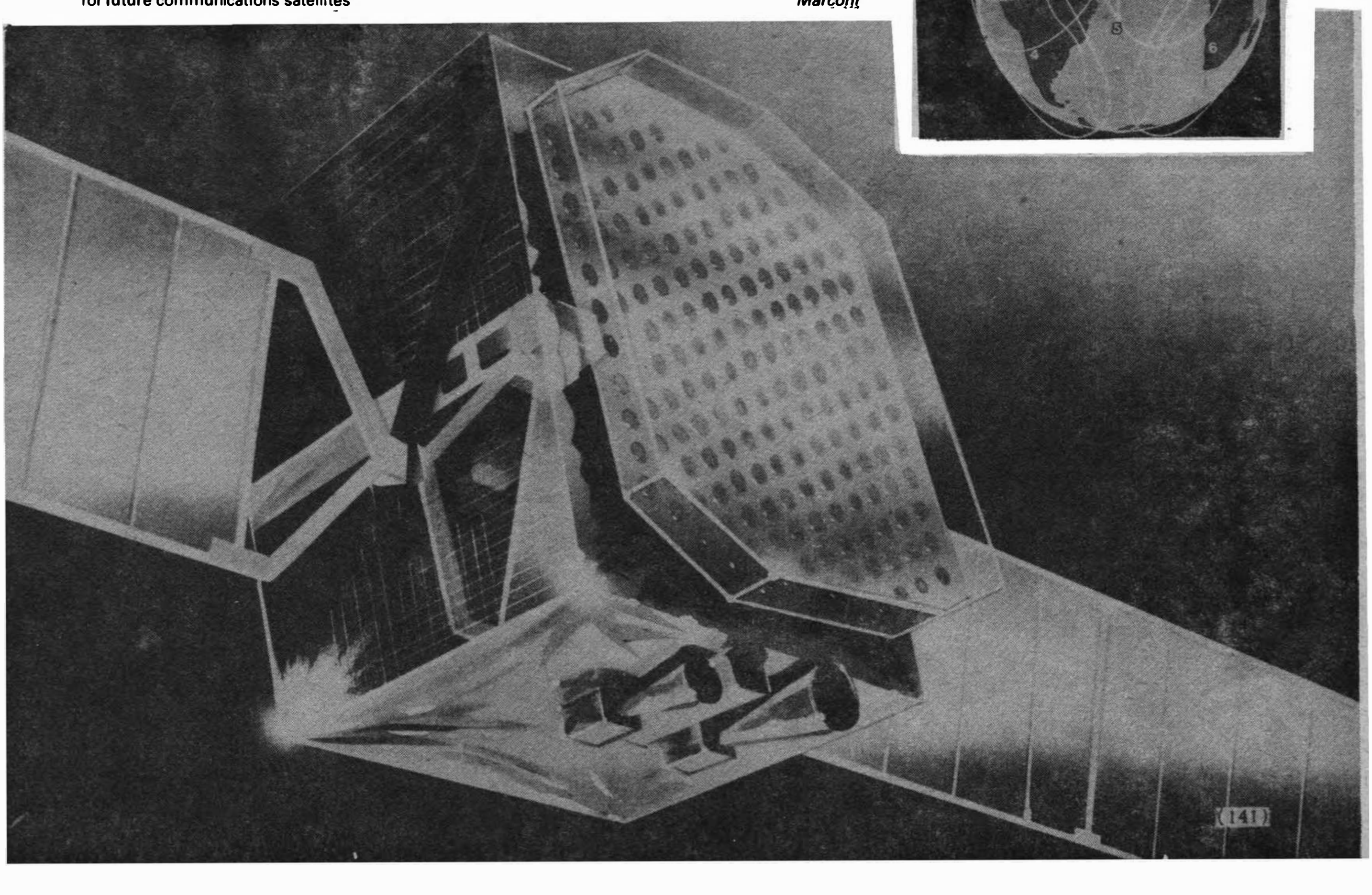
Operating in the L-Band satellite communications spectrum (1.5 – 1.6 GHz), the system design will provide six fixed spot beams and two steerable spot beams. Global coverage will be provided simultaneously, thus maintaining compatibility with existing satellites.

The GEC-Marconi group, Britain's largest space industry employer, was represented by four of its companies at Space Commerce '88 – Marconi Space Systems, Marconi Communication Systems, Marconi Defence Systems and Marconi Marine.

Among products on show were a Newshawk mobile Earth station for newsgathering, a TPO1 man-portable communications terminal, a Desert Ray vehicle-borne Inmarsat terminal, an Ocean Ray marine satcom terminal and models of the ERS1, Meteosat, Eutelsat and Aramis satellites.

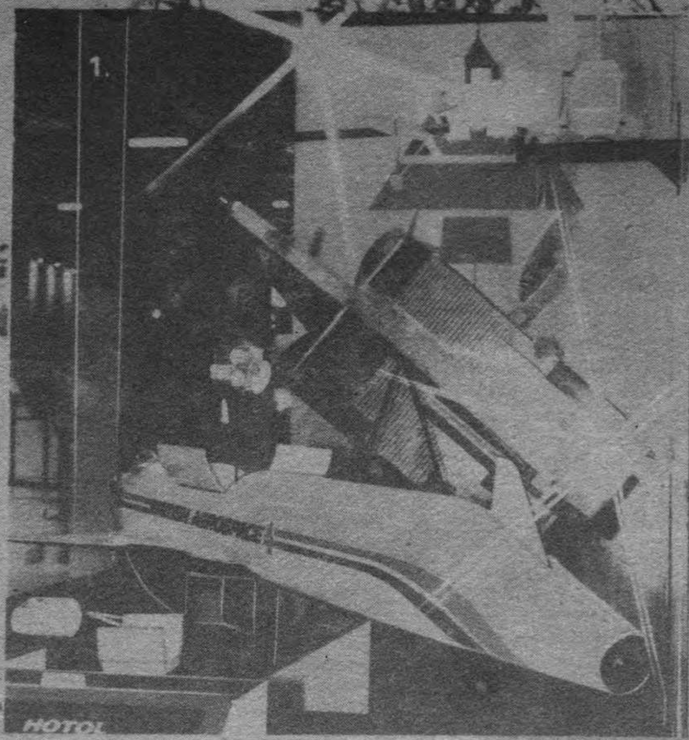


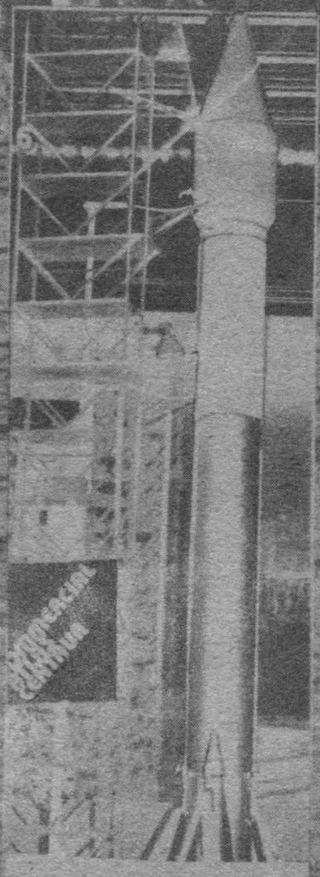
The advanced L-Band payload (Aramis) will provide six fixed spot beams and two steerable spot beams for future communications satellites *Marconi*

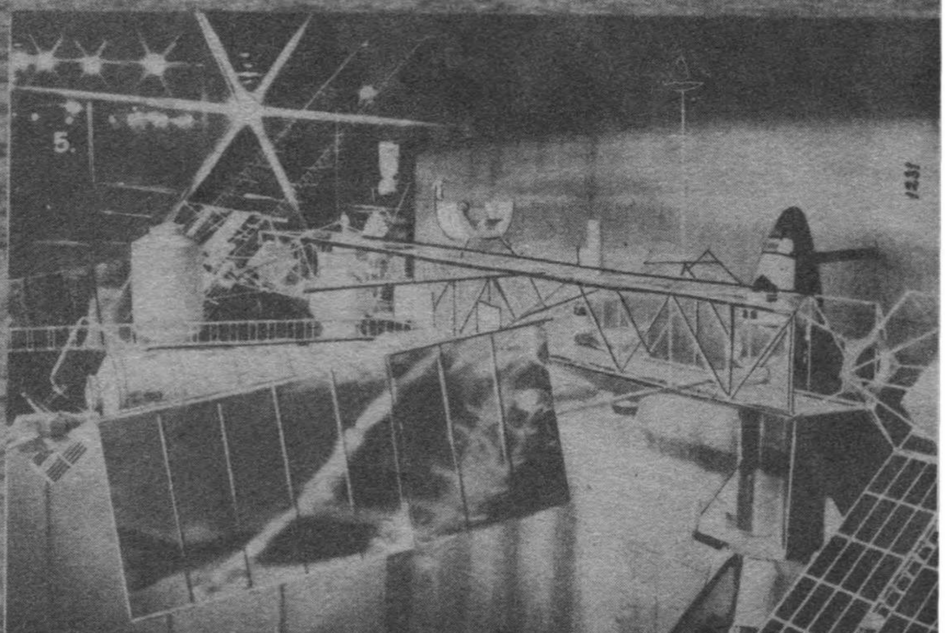


SPACE COMMERCE '88

Pictures: C.A. Simpson







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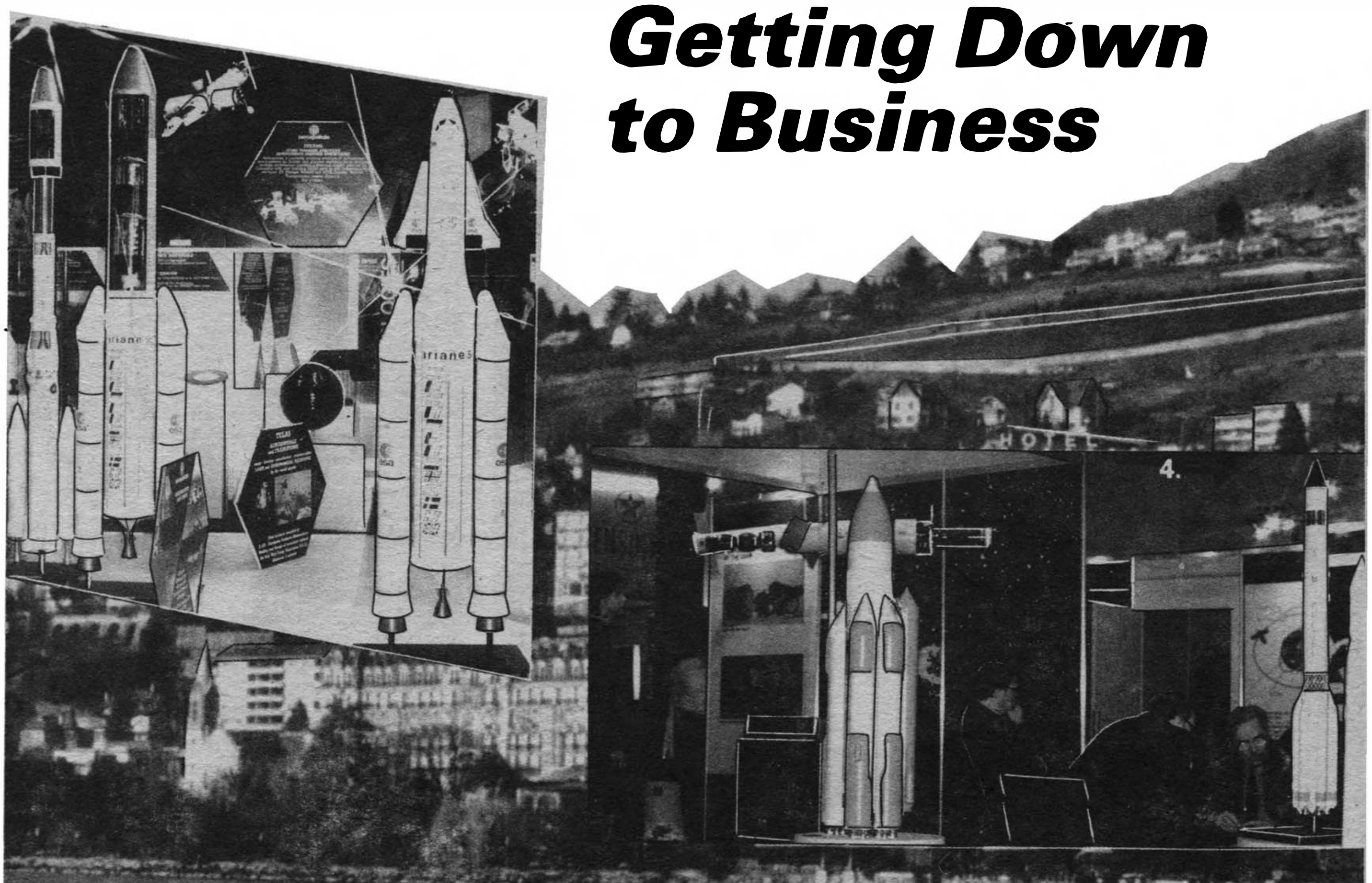
Getting Down to Business



Letter from Montreux

Competition on the 'Space Circuit' for exhibitions and conferences is getting tough and the idea of holding a major space gathering in the attractive Swiss resort of Montreux may seem somewhat unconventional. However, for the second time, Space Commerce '88 has proved a significant draw for a representative selection of the world's space industry.

Space Commerce '88 (the first was held in June 1986 and the next is promised for June 1990) at the end of February was promoted by the enterprising local authority in Montreux, which hopes to break even on the venture next time round.

Attendance this year was around 300 and there were some significant new additions to the exhibition with representatives from 12 nations.

Important 'firsts' for Space Commerce '88 were major exhibits from NASA and the Soviet Union.

The Glavcosmos/Licensintorg stand was a hive of activity. The now customary models of Proton, Energia, Mir, Phobos etc. were backed by photographs, space artifacts and a video display. 'Give-aways' included brochures, posters and badges. The back-up in personnel was impressive, with numerous members of the Soviet delegation (and interpreters where necessary) on hand to discuss business. Alexander Dunayev, Glavcosmos chairman, was among those in attendance.

US input to Space Commerce '88 was headed by NASA with its own hospitality suite and display area fronted by an impressive large-scale model of the future international space station being serviced by a space shuttle.

Rockwell, Lockheed, Martin Marietta, General Dynamics, EOSAT and Fairchild were among other US companies to take major stands.

The UK contingent was formed by British Aerospace, GEC/Marconi and Singer Link Miles (slightly disappointing there was not a wider representation, although understandable in the light of recent British government statements).

Germany, France and Italy were all strongly represented, and NASDA (Japan's national space development agency) had its first stand at this exhibition.

According to the organisers, the Space Commerce series of exhibitions and conferences aims to contribute to the development of commercial space products and the services they provide by bringing together potential user industry representatives and aerospace specialists.

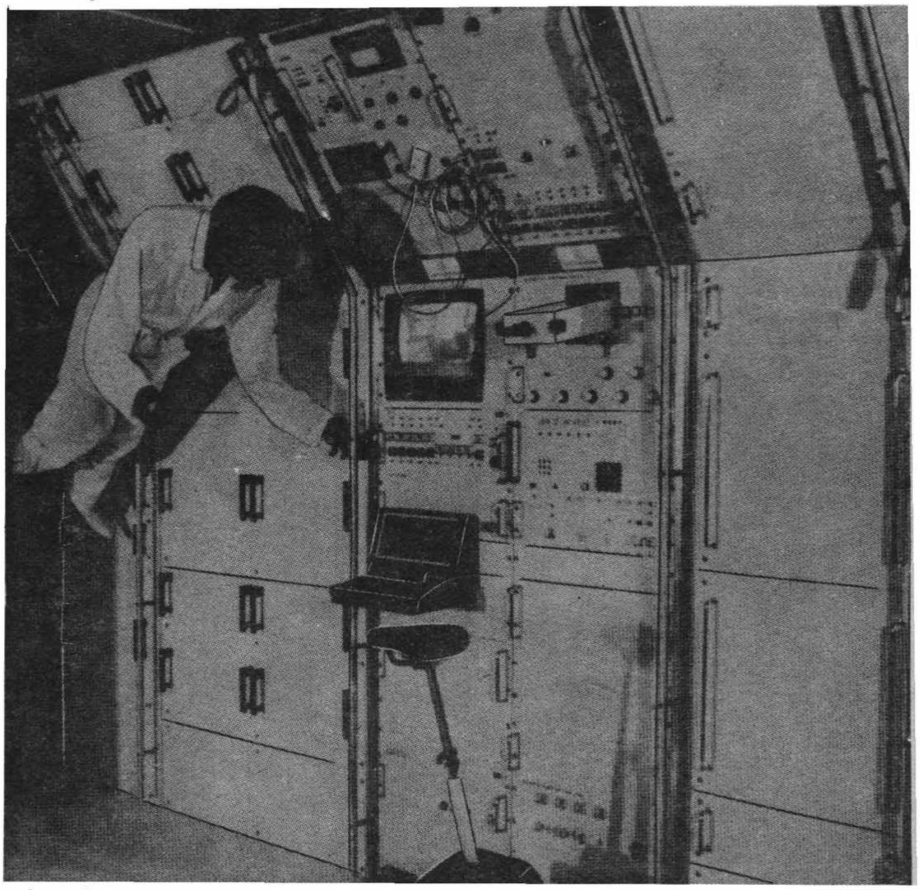
Superb Swiss organisation and a spectacular setting thrown in for good measure are just part of the answer to a successful exhibition/conference venture. The real test will come in two years' time.

C.A. Simpson

Key to pictures:

1. Hotol, Olympus and Polar Platform models flank the entrance to British Aerospace's stand which was primarily promoting the company's expertise in communications satellites.
2. Eutelsat which looks after the space segment operations for European telecommunications organisations.
3. Aerospatiale, a spectacular display, including models of Ariane 4/5, Hermes and various satellites.
4. Glavcosmos/Licensintorg.
5. NASA model of the international space station and US shuttle.
6. Large-scale model of the commerical Atlas Centaur launcher formed the centrepiece of the General Dynamics stand.

INTERNATIONAL SPACE REPORT



European Space Laboratory

Aerospatiale has signed a contract for 103 MF for the development (phase C/D) of the human physiology laboratory, Anthrorack. A full-sized model of the laboratory (see picture) was on show at Space Commerce '88.

Part of ESA's phase 2 microgravity programme, Anthrorack will fly aboard Spacelab on the D2 mission with the US space shuttle planned for 1992.

Three models will be built: one for crew training which will be delivered in the middle of this year; a qualification model to be used by scientists for preparation of their experiments, which will be delivered at the end of 1988; and a flight model to be delivered in the middle of 1989.

Aerospatiale, as prime contractor is responsible for the development of the infrastructure and integration of Anthrorack in its Aquitaine centre.

Aerospatiale will also train the Spacelab crew which will use Anthrorack and will provide technical assistance to cooperating scientists before and during the flight.

Aerospatiale's industrial team for Anthrorack includes: Amis (Denmark), CIR (Switzerland), Crisa (Spain), DFVLR, MBB, OHB and Panares (FRG), Thomson SA/NV, Verhaert and Logica (Belgium), ICG (United Kingdom) and Matra (France).

Germany Loses New DBS Satellite

Attempts to activate the West German TV-Sat satellite appear to have failed and the vehicle, launched by an Ariane on November 20, is expected to be written off.

Problems began soon after the launch when it was determined that one of two solar panels had failed to deploy. It is believed that catches, which should have released the folded panel, failed to unlock.

Several attempts to free the solar panel by spinning the satellite have proved unsuccessful.

As well as causing a severe reduction in power the jammed panel has effectively blocked proper deployment of the satellite's receiving antenna, meaning no chance of partial operation using power from the other solar panel.

TV-Sat 1 was to have been used to begin beaming digital TV and radio programming direct into homes in West Germany and other European countries. TV-Sat 2 is currently scheduled for launch in August 1990.

The West German satellite is the same design as the French TDF-1 which, after minor modifications, is still expected to be launched by Ariane on time at the end of the summer.

France's Telecom IB telecommunications satellite, launched in May 1985, failed in orbit on January 15 due to faults in both the primary and back-up atitude control systems.

Airliner Communications

A TAP-Air Portugal Lockheed Tristar became the first commercial aircraft to use satellite data communications on a transatlantic flight during February, as part of a joint Inmarsat/European Space Agency experimental development programme.

The aircraft, on a regular flight from Lisbon to New York, maintained continuous contact throughout the transoceanic journey via the Inmarsat Atlantic Ocean satellite.

Communications were routed through the ESA Earth station at Villafranca, Spain, and the airline communications network operated by SITA.

The airborne satellite terminal, which provides data links for cockpit and crew communications and passenger telex, has been developed by ESA. Established under a test and demonstration agreement between SITA and Inmarsat, the trials are expected to continue for a period of two years, with individual aircraft participating for several months. Other airlines involved in the trials are Air France, Sabena and Varig.

* * *

Nigeria became the 54th member country of Inmarsat at the end of February. The sixth African country to seek membership, Nigeria already has two ships using the Inmarsat satellite communications system and also generates considerable shore to ship traffic.

INTERNATIONAL SPACE REPORT

British Space Consultants for China

UK firm, Vega Space Systems Engineering, has been appointed by the China Great Wall Industry Corporation as Technical Advisers in the promotion of the Long March family of satellite launch vehicles.

The appointment is the first space consultancy contract China has ever placed in the West. Vega was selected on the basis of experience in system engineering and its independence from the western launch vehicle suppliers.

The company's role will be to:

- Assist in the definition of a streamlined spacecraft/launch vehicle integration process, which will be described in new Users' Manuals, prepared by Vega, for the launchers and launch site facilities.
- Assist CGWIC in the presentation of the Long March launchers to potential customers and in resolving interface problems.
- Improve communications between CGWIC and customers in the West, by providing a European repository of information about the Long March launchers, and by being a focal point for all technical queries.

The Chinese series of Long March rockets have varying degrees of capability, ranging from 900 kg to 9000 kg payloads to low-Earth orbit, 1400 kg to geosynchronous transfer orbit and 1500 kg to Sun-synchronous orbit. Under an agreement with McDonnell Douglas, Payload Assist Module (PAM) upper stages can also be offered in conjunction with the Long March (***Spaceflight***, December 1987, p.405).

China, with a manufacturing and launch capability of about 12 Long March launchers per year (of which up to half would be used for domestic satellites), is aiming its launch service at making up the shortage in the current world launcher market.

The relatively low price makes the Long March launchers particularly attractive to other developing nations wishing to establish their own space systems.

US Satellite on Ariane V21 Mission

Final countdown was expected to proceed as normal by Ariane space for the launch of two telecommunications satellites from the French Guiana launch site in the early hours of March 12.

The Ariane 3 launcher, on mission V21, was due to place in orbit Spacenet III/R belonging to the GTE Spacenet Corporation and Telecom IC, owned by the French government.

Proton to Launch Indian Spacecraft

The first in a series of Indian remote sensing satellites, IRS 1-A, was due to be launched by a Soviet Proton rocket last month (March).

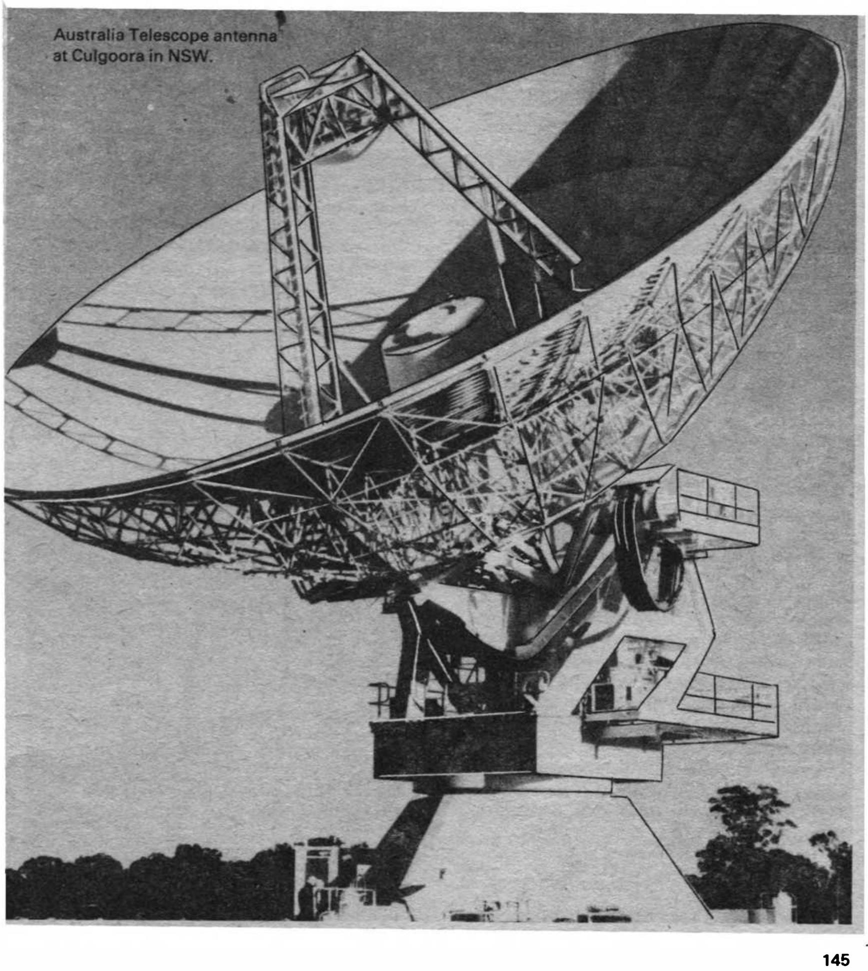
Designed and developed by the Indian Space Research Organisation (ISRO), it has a planned design life of three years.

Australia Joins International Space Probe Network

Astronomers throughout the world are linking a number of powerful radio telescopes into a network which will probe and map deep space beyond our galaxy more accurately than before.

Australia's part of the international network – the $43 million Australia Telescope – will begin operating this year as part of the Australian bicentennial celebrations.

The Australia Telescope will consist of an array of 22 m (72 ft) antennas in rural New South Wales (NSW) – six at Culgoora, one at Mopra near Siding Spring and the existing CSIRO radio telescope at Parkes.


Australia Telescope antenna at Culgoora in NSW.

Spaceport Consortium

Australia's Queensland state government has announced that the Cape York Space Agency (CYSA) has been selected to coordinate efforts to build a full-scale equatorial launch site by 1993.

A two year feasibility study into the private enterprise spaceport on Australia's northern-most tip will be the agency's first task.

CSYA is a consortium of 64 companies, mainly Australian but including Japan's Shimizu Corporation.

A major report on Australia's plans for a 21st Century spaceport appeared in **Spaceflight**, *June 1987, pp.230-232.*

SATELLITE DIGEST – 211

Robert D. Christy

Continued from the March 1988 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

RADUGA 21, 1987-100A, 18631
Launched: 1130, 10 December 1987 from Tyuratam by D-1-e.
Spacecraft data: Probably similar to the Gorizont satellites, being a stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links within the USSR.
Orbit: Geosynchronous above 128 degrees east.

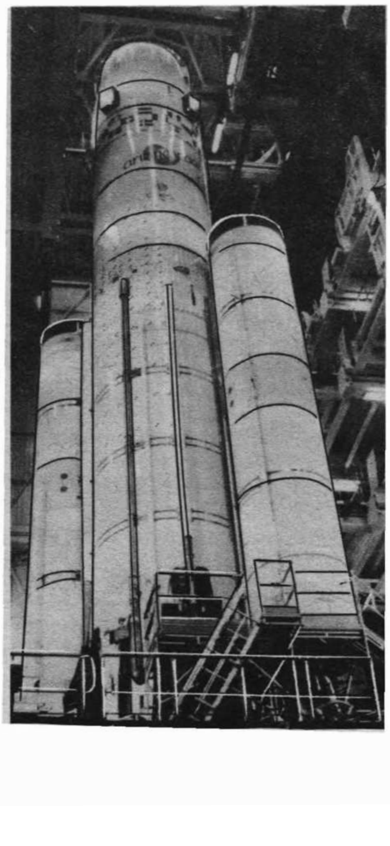
COSMOS 1900, 1987-101A, 18665
Launched: 0710, 12 December 1987 from Tyuratam by F-1.
Spacecraft data: Combined satellite and final rocket stage, around 7 m long and 2 m diameter with a mass around 5000 kg. A slot-type radar aerial is fixed to one side of the body. Power is provided by a nuclear reactor.
Mission: Radar reconnaissance over ocean areas.
Orbit: Slightly higher one than usual at 257 x 271 km, 89.80 min, 65.00 deg, maintained by a low thrust motor during the operational lifetime. Later, the nuclear power source is expected to be boosted to a 900-950 kilometre high, circular orbit to delay re-entry into the Earth's atmosphere.

COSMOS 1901, 1987-102A, 18666
Launched: 1130, 14 December 1987 from Tyuratam, by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 174 x 355 km, 89.81 min, 64.91 deg, manoeuvrable.

COSMOS 1902, 1987-103A, 18668
Launched: 1332, 15 December 1987 from Plesetsk by C-1.
Spacecraft data: Not available.
Mission: Small, military satellite, possibly for use as a calibration target for ground-based radars.
Orbit: 368 x 411 km, 92.36 min, 65.84 deg.

SOYUZ-TM 4, 1987-104A, 18699
Launched: 1118*, 21 December 1987 from Tyuratam by A-2.
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried crew of Vladimir Titov, Musakhi Manarov and Anatoly Levchenko to Mir. Titov and Manarov then took over as the resident crew while Levchenko, who flew in connection with Soviet shuttle-related experiments returned to Earth within Soyuz-TM 3 with the earlier Mir crew of Yuri Romanenko and Alexander Alexandrov. Soyuz-TM4 docked with Kvant at 1251 on 23 December. At 0910 on 30 December, with Titov and Manarov aboard it undocked and then re-docked at Mir's forward port, 19 minutes later.
Orbit: Initially 168 x 243 km, 88.55 min, 51.61 deg, then by way of a 255 x 296 km transfer orbit to a docking with Mir in an orbit of 333 x 359 km, 91.40 min, 51.63 deg.

Work on preparing the first Ariane 4 for launch (scheduled for this month – April) has been continuing apace. In this picture the lower section of the vehicle, with twin strap-on boosters, can be seen on the launch table of ELA-2, French Guiana. *Aerospatiale*



COSMOS 1903, 1987-105A, 18701
Launched: 2235, 21 December from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 583 x 39282 km, 707.88 min, 62.91 deg, then raised to 586 x 39759 km, 717.57 min, 62,99 deg to ensure daily repeats of the ground track.

COSMOS 1904, 1987-106A, 18709
Launched: 2023, 23 December 1987 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 968 x 1009 km, 104.94 min, 82.92 deg.

COSMOS 1905, 1987-107A, 18711
Launched: 0845, 25 December 1987 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance,

recovered after 14 days.
Orbit: 207 x 273 km, 89.34 min, 70.34 deg.

COSMOS 1906, 1987-108A, 18713

Launched: 1130, 26 December 1987 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, normally recovered after 14 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme. On 31 January 1988, it exploded following an earlier, apparently failed, attempt at recovery (see p.161).
Orbit: 257 x 276 km, 89.91 min, 82.60 deg.

EKRAN 17, 1987-109A, 18715

Launched: 1125, 27 December 1987 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with an aerial array in the form of a 6 m x 2 m rectangular panel at one end. Electrical power is provided by a pair of rotatable, boom mounted solar panels at the opposite end of the body, and positioned at right angles to it. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing television and radio services to community aerials in remote areas of the USSR.
Orbit: Geosynchronous above 99 deg east.

COSMOS 1907, 1987-110A, 18720

Launched: 1140, 29 December 1987 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 356 x 415 km, 92.31 min, 72.83 deg.

UPDATES: 1987-63A, Soyuz-TM3 undocked from Mir at 0555 on 29 December and landed near Arkalyk, Khazakhstan at 0916 the same day. It was carrying cosmonauts Romanenko, Alexandrov and Levchenko.

NASA Launches Delta Rocket

NASA launched the Delta 181 mission on February 8, following a perfect countdown. Launch director James L. Womack characterised the launch as "perfect" and stated that lift-off time occurred exactly as scheduled, *writes Roelof L. Shuiling.*

Delta 181 was a 3910 McDonnell Douglas vehicle. The 3910 series has a Rocketdyne RS-27 liquid fuelled first stage engine which produces 93,000 kg of thrust. The second stage has two TRW TR-201 storable liquid fuel engines and provides 4,450 kg of thurst.

In addition, the 3910 series has nine solid booster rockets which produce 347,400 kg of thrust. The solid boosters are ignited in two groups – one at lift-off and the second during the flight. The 3910 series launch vehicle has been extensively used in the past to launch commercial communications satellites.

Following the launch, telemetry indicated that the initial orbit was within one kilometre of that which had been planned. Four burns of the second stage occurred during the mission. The first placed the stage in a transfer orbit, after which the second burn placed it in operational orbit. A circularising burn was later performed followed by a depletion burn.

The payload was a Strategic Defense Initiative sensor package which tracked a series of test objects round the Earth. Following the active phase of the mission the payload was placed in a gravity gradient attitude and data was downlinked to ground stations during the following two weeks.

* * *

The US Air Force has ordered seven more McDonnell Douglas Delta II rockets for $161 m.

By placing the order, the Air Force exercised its first option on an earlier contract worth $316 m, for seven Delta II's. The contract still carries a second option for six more medium launch vehicles, which would bring the total contract value to about $680 m, including launch services.

The Delta II will be used primarily to boost the Air Force's Navstar Global Positioning System (GPS) spacecraft into orbit. The GPS is a navigation satellite system the Air Force will use to provide "pin point" accuracy for users anywhere on the globe.

In addition to the Air force business, McDonnell Douglas has received five contracts for use of two Deltas and three Delta II's in launching satellites for commercial and civilian purposes.

Microgravity Experiments

A Swedish sounding rocket was successfully launched from the Kiruna range in northern Sweden on February 29.

The payload, carrying seven European Space Agency experiments out of a total of eight, was flown in microgravity conditions for seven minutes and 18 seconds. The basic research covered areas such as immiscible alloys, metallurgy, growth of semiconductors, as well as the heat transfer and surface tension properties of liquids.

During the flight, two scientists in the field of fluid science were present at the range and were able, by means of live television links, to see in real time the progress of their experiments.

Microgravity research is carried out in the free floating conditions obtained in orbital and sub-orbital space flight where near weightlessness of about one ten thousandth of the force of gravity at the Earth's surface can be obtained.

Sweden's Maser sounding rocket programme and the German Texus programme are currently providing a growing scientific community with the means to carry out experiments in a rapid, flexible manner at regular intervals until the time the international space station/Columbus is operational.

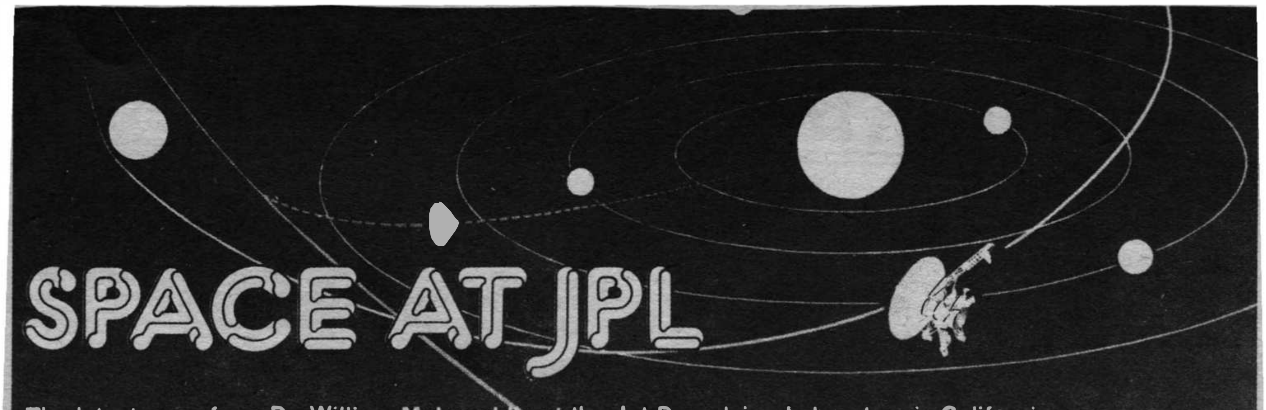
Japan Orbits Satellite

Japanese communications satellite CS-3a was launched by an H-1 rocket from Tanegashima on February 19.

The 550 kg, spin-stabilised satellite was injected into a geostationary orbit and has a projected lifetime of seven years.

CS-3a is the latest in a series of Japanese communications satellites developed to meet increasing and diversifying communications demands and to develop advanced satellite communications technologies. The first satellite in the series, CS 'Sakura', was launched in December 1977 by a US Delta rocket.

The CS-2 satellites (2a and 2b) were launched by Japanese N-11 rockets in February and August 1983.



The latest news from Dr. William McLaughlin at the Jet Propulsion Laboratory in California.

JPL Telerobot

The Civilian Space Technology Initiative within NASA is designed to foster technological advances which will strengthen the Agency's ability to perform its role of exploration. As part of this effort the NASA Robotic Testbed Project at JPL is being developed in cooperation with universities, industry, and other NASA Centres. Combining core research with a series of demonstrations, the evolving telerobot will serve as a guide to the design and construction of a Flight Telerobot Servicer (FTS) for the space station and could influence to advantage other automated missions such as the Mars Rover Sample Return (see the November 1987 edition of this column).

A telerobot is a device which blends human control with autonomous operation in a dynamically smooth manner. "Tele" is a Greek word which means "far off" and figures in many compounds ("television", "telephone," etc.), and, as employed here, signifies human participation from a distance. The word "robot" arises from the 1923 play *R.U.R.* by Czech dramatist Karel Capek where conflict between humans and robots is depicted; "robota" is Czech for "work".

The project manager for the Telerobot is David B. Smith of JPL. He said that the knowledge gained through building and operating the telerobotic testbed will make NASA "a smart customer" in procuring elements of the FTS through the industrial contracting process ("system contracting"). The FTS, which is managed by NASA's Goddard Space Flight Center, will see requests-for-proposal issued to industry this summer. Important support from the telerobotic testbed will be manifested in FTS development at key points such as the preliminary design review in 1989 and the critical design review in 1991. The system is scheduled to be in operation by the beginning of 1994.

The Robot Systems Division of the US National Bureau of Standards has put together the NASA Standard Reference Model (NASREM) for a telerobot control system, and the telerobot is designed, overall, to be in functional compliance with this model. NASREM is hierarchically structured into several layers which range from detailed activities (e.g., coordinate transformations) to high-level activities (e.g., assignment of resources). In addition to this vertical structuring, NASREM is divided horizontally into three sections: task decomposition (for convenience in subsequent processing), world modelling (the telerobot's mathematical view of its environment), and sensory processing.

Although the broad functional design of NASREM exists and there is much experience with industrial robots in a controlled workplace, the telerobot being developed is a state-of-the-art device. The advance it represents is the set of capabilities that allow it to function successfully in the changing and uncertain conditions of on-orbit assembly and servicing as contrasted, say, to the calibrated niche in which an automobile-assembly robot works.

Smith listed the three major challenges which the telerobot faces.

First, putting an overall NASA programme together poses a significant management problem since advanced constituents of the telerobot are being developed at other NASA centers around the country. They must come together for demonstrations, or sometimes, due to cost or schedule constraints, arrangements must be made to demonstrate in a meaningful way capabilities that are physically separated.

Second, there is a technical challenge related to advanced, cooperative control systems. The telerobot can be designed to provide cooperative behaviour between its arms and head (vision subsystem). For example, a telerobot, a two-armed entity, often needs to reach to full extension in order to grab a tool or remove a bolt. To achieve this reach, one arm can pull back to allow the other to maximise its stretch: an act which humans do without thinking but must be built into the circuits of a machine. Another example of cooperation is furnished by coordinated behaviour between orientation of the telerobot's vision system and use of an arm. Think of the advantage accrued by the instinctive positioning of your head to observe and control better your manual use of a tool. The present control system of the telerobot exhibits a degree of cooperative behaviour through the handling of an object using two hands. This technique of cooperation employs one arm as a master for position control while the other is slaved to it through the requirement of exerting zero force on the object being carried.

The third major challenge is to incorporate a sensing system into the control system. At present, the telerobot calibrates its work space to within an accuracy of about 2 mm and proceeds to "work in the blind" until the next update is made via information obtained through its vision and tactile sensor system. With a continuous updating capability the telerobot could efficiently adapt to a changing environment. Smith likened this capability to the action of a quarterback in American football who continuously gauges the motion of a receiver before throwing the ball 30 yards downfield, into outstretched hands.

Control of the telerobot can be handed off between the human operator (teleoperation) and the Telerobot Interactive Planning System (TIPS) as the situation requires. In the teleoperator mode the human has available the vision system of the telerobot and various other services. For example, a TIPS function is to plan the gross (as opposed to "fine") spatial motion of the telerobot arms. The results of this planning can be used either to run the machine autonomously or display the arm motions, by graphical means, so that the human operator can learn and then emulate the appropriate actions.

According to the current plan, teleoperation will be enhanced in 1991 when a vision helmet provided by NASA's Ames Research Center is integrated into the testbed. Wearing the helmet the operator sees the work place from the telerobot's perspective and also sees wire-frame hands representing the telerobot's appendages.

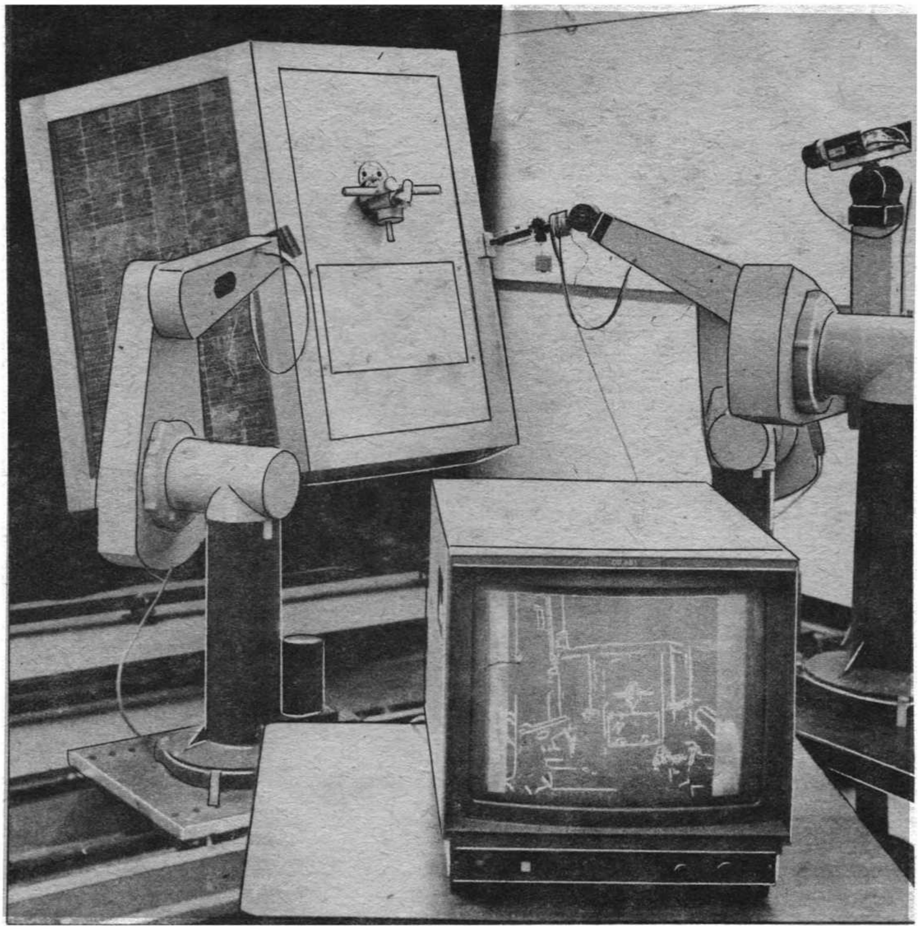
Motion of the human's arms is sensed by a surrounding magnetic field and mapped into motion of the wire-frame hands and those of the telerobot itself. The wire-frame hands provide visual feedback to the human on the progress of the task.

The TIPS, as mentioned, computes the gross spatial motions of the arms, i.e., their collision-free trajectories through space to the vicinity of a material object, like a bolt to be removed. A higher-level function of the TIPS is task planning: laying out a sequence of actions sufficient to accomplish the job. The third primary function of the TIPS is kinematic simulation wherein commands are checked to ensure that they satisfy operational constraints (in autonomous operation) before they are sent to the next level of the telerobot system.

This next (lower) level of the hierarchical system is the Run Time Controller (RTC). The three primary functions of the RTC are fine-motion planning, collision avoidance, and maintenance of the telerobot's world model. Fine-motion planning commences after hand off from the TIPS, which has brought the arm as a result of gross spatial planning to the immediate neighbourhood where the hand is to perform. High-level collision avoidance is checked in the TIPS; final avoidance checks take place in the RTC. Maintenance of the data base is done through black and white vision and position sensing using the "teach pen" method. It is anticipated that colour vision will be added as an additional data type to update the world model of the telerobot. Consider the additional information we humans derive from observing the effect of light and shading on coloured surfaces (see "Space Artist" in the November 1987 edition of this column). Mathematical descriptions of these colour phenomena are well known to illumination engineers, and hence, information can be extracted from colour sensors to improve knowledge of where things are in the telerobot's work place. Another data type will become available when a laser-ranging system being developed by NASA's Langley Research Center is built into the arms of the telerobot.

Continuing down the hierarchical architecture, we encounter at the level below the RTC the Sensing and Perception subsystem and the Manipulation and Control Mechanization (MCM) subsystem. The functions of the former are self-explanatory. The MCM interfaces with either the RTC (in the autonomous mode) or the human when teleoperation is in effect. It translates the desires of the RTC or the human into the proper control law, sets gains, and performs other such tasks that only a dedicated engineer or a machine could enjoy.

The lowest level of the hierarchy, before arm motion is effected, is occupied by the Universal Controllers that specify currents and torques needed to fulfil the course designed by the hierarchical chain of human/TIPS, RTC, MCM and the Universal Controllers.



The Telerobot being developed at JPL blends human and autonomous control and supports the design and implementation of NASA's Flight Telerobot Servicer which will be utilised for the space station.
NASA/JPL

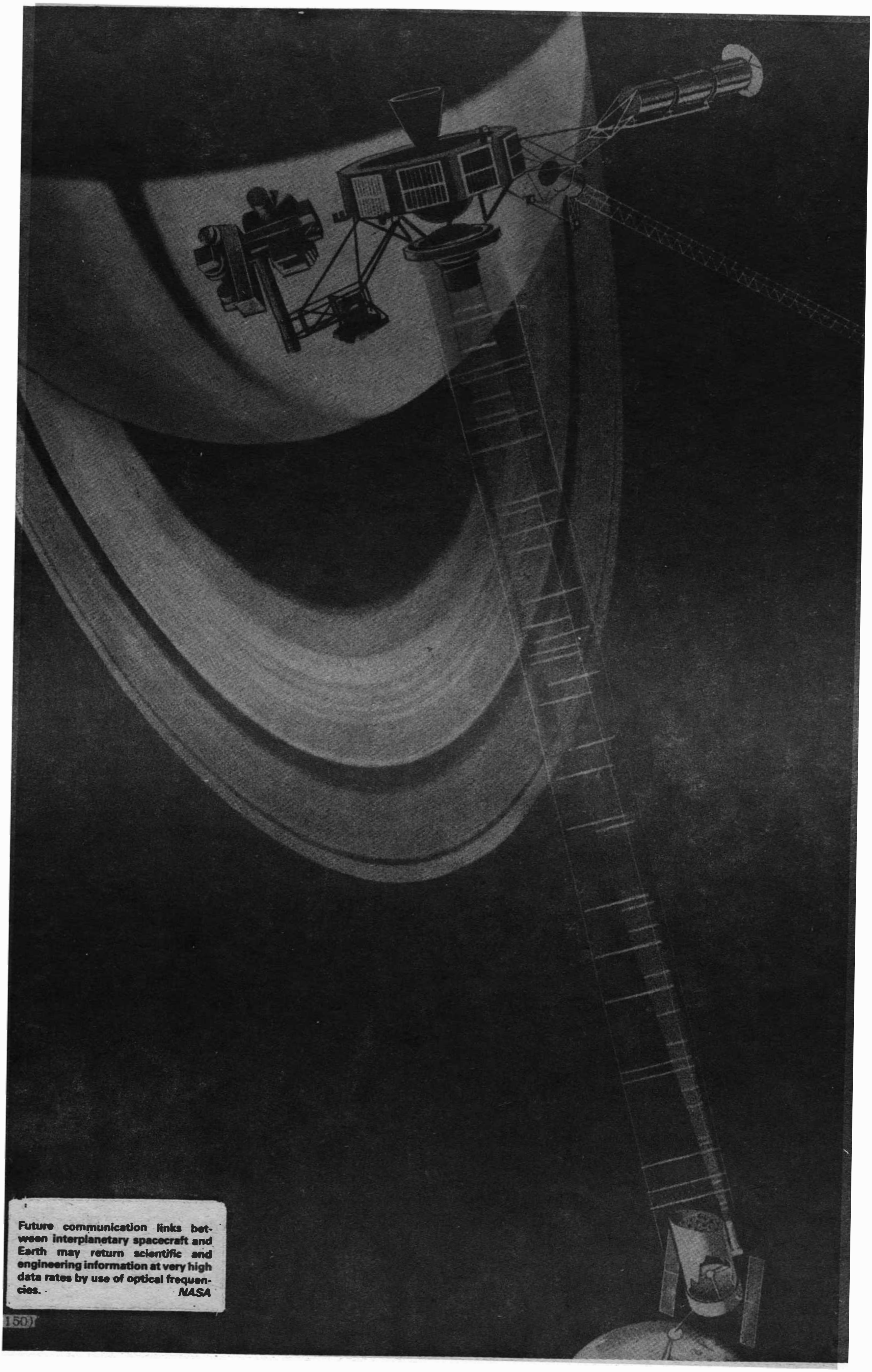
The arms now on the telerobot are Puma 560 models, used for industrial applications. They have an ability to lift five pounds and articulate in six degrees of freedom obtained through motions of "shoulder", "elbow", and "wrist". Late this year, arms with a 25-pound capacity and seven degrees of freedom will be installed after delivery from Robot Research, Inc. of Cincinnati.

The added ability to lift will support addition of "smart hands" to be end effectors for the arms. These end effectors, containing microprocessors, will be able to perform the final steps of tasks, like bolt removal, after being positioned over the bolt by upper levels of the system.

The seven-degree-of-freedom arms allow distribution of turn angles in a larger number of places than for the six-degree-of-freedom version. The problem that is being avoided is the accumulation of too much angular twist in any one joint. Imagine a human attempting to effect a rotary motion of a tool by only turning the wrist, with no cooperation from elbow or shoulder; an awkward pose would result. "Pose changes" in the telerobot are actions taken to relieve excessive angular accumulation in a joint. Sometimes one arm has to come to the aid of another by holding an object for the afflicted arm while it unwinds through a pose change. The avoidance of the necessity for pose changes is facilitated by having numerous degrees-of-freedom available for absorbing rotation, but avoidance procedures still constitute a difficult planning problem. Once again, what comes naturally to a human furnishes a challenging problem in analysis for designers.

Smith said that the present computing system for the telerobot, a microVAX (the TIPS is hosted on a Symbolics machine), will have to be upgraded to accommodate the complexity added by more degrees of freedom, new sensor types, improved control features, etc. Eventually, a commercial N-Cube with 64 nodes may be placed in the system (see the May 1987 "Space at JPL" for a description of hypercube-type concurrent computers).

Buoyed by a highly successful demonstration of an integrated set of capabilities in February of this year, the project continues to move into the realm of joint human/machine cooperation, a domain which is not only useful but also intriguing as to where it may ultimately lead.



Future communication links between interplanetary spacecraft and Earth may return scientific and engineering information at very high data rates by use of optical frequencies. *NASA*

Measuring Information

The fact that the world is uncertain gives rise to a broad spectrum of activities: planning, betting, and buying insurance, for example. Venerable practices of coping with equivocation have been augmented by the introduction of precise methods of measuring uncertainty and, concomitantly, the information which reduces or removes uncertainty. Often in this column the flow of information from spacecraft to Earth has been described not only in terms of its scientific and engineering content but also by its quantity: enter the "bit".

Information theory had its first stirrings over 60 years ago in the works of Harry Nyquist and R. V. Hartley, but it came of age in Claude Shannon's two-part paper, "A Mathematical Theory of Communication", published in 1948. In this, and subsequent papers, Shannon created fundamental tools which assist us in the design and analysis of communication systems that must function in this imperfect world where noise and the limitations of equipment often seem to conspire to impede the flow of information.

The term "bit" is a contraction of "binary digit" and is the basic unit of measurement for a stored or transmitted quantity of information. Consider the case where Person A is contemplating the imminent result of a distant event that can have two outcomes; call them "success" and "failure", and symbolize them by 1 and 0, respectively. After the event has been determined and an observer reports the outcome by transmitting the message "1" (success) or "0" (failure) to Person A, we say that Person A has acquired one bit of information. Similarly, observing the result of flipping a fair coin, or any other binary experiment, yields one bit of information.

In general, the number of bits of information associated with learning the outcome of an experiment equals the logarithm (base 2) of the number of possible outcomes; for this simplified definition, it is assumed that each of the outcomes is equally likely. Thus, an 8-outcome experiment would generate three bits of information since $2^3 = 8$ (for the bit from the binary experiment, $2^1 = 2$ applies).

The use of the logarithm to measure an amount of information is not an obvious step, but it turns out to be wonderfully convenient. Some intuitive feel for the meaning of the bit measure of information can be obtained by recognizing that it specifies the number of binary digits that must be employed in order to enumerate the number of possible outcomes. Thus, a single binary digit (which can be 1 or 0) suffices to enumerate the two outcomes of the binary experiment, while an experiment with four outcomes would require two binary digits, and have two bits (the four binary-number enumerators are 00, 01, 10, and 11).

In the more complex case of the Voyager spacecraft flying by a planet, the same principles can be applied to measure the amount of information it will be necessary to transmit to Earth from, say, the activity of the imaging process. The focal plane of the camera consists of 800 x 800 picture elements ("pixels") and each pixel is capable of registering one of 256 brightness levels (which is converted to an electrical signal for further handling). The most primitive camera one could imagine would consist of only one pixel with two brightness levels, and we would be back to the binary case previously discussed; each "picture" would contain 1 bit of information. Now, for the real case $2^8 = 256$ so each Voyager pixel has associated with it exactly 8 bits of information. An entire picture has 8 x 800 x 800 or somewhat over 5 million bits.

Note the convenience of the bit measure since the total number of bits for the entire focal plane is just the sum of the bits associated with each pixel.

The theory of Shannon was applied to the Voyager telecommunications link from spacecraft to Earth to conclude that, at Saturn, data could be returned at a maximum of about 44.8 kilobits per second while at the greater distance of Uranus, the rate would top out at 21.6 kilobits per second. Dividing this latter rate into the number of bits per picture shows that it took approximately five minutes to transmit a Uranian picture to Earth. If the spacecraft's antenna were not pointed toward Earth at the time of picture taking, the image would be recorded on the onboard tape recorder for later transmission to Earth. The capacity of the tape recorder is also measured in bits (about 550 million), so that planning the recording and transmission strategy during a busy encounter is greatly facilitated by the ability to measure amounts of information.

However, not all bits are equal. Before we return to the data system of the Voyager spacecraft, let us examine an additional concept of information measure by making a digression through the information content of the English language.

Consider a series of letters comprising an English text, such as the present paragraph. If we assume that 40 kinds of different symbols are used (26 letters of the alphabet, the "space", 10 numerals, and a few symbols for punctuation), then each symbol of text would reveal approximately 5.32 bits of information: the (base 2) logarithm of 40. So, a five-letter word would convey 26.6 bits of information, and a book of 100,000 words would contain about 2.66 million bits (approximately half that of a Voyager image – which says something about a certain ancient proverb on the worth of a picture).

But this estimate of the information in text assumes that each succeeding symbol is independent of the symbols that went before it. This is not the case due to rules of English composition which are encoded in the canons of grammar and spelling. When a "q" appears, we almost always expect to see it followed by a "u". Thus, the actual appearance of a near certainty, the "u" in this example, does not convey as much information to the reader as if there were no correlation between "q" and "u". In addition to correlations between symbols, not all letters appear with equal frequency; "e" has a frequency of over 10 per cent in most text (but, surprisingly, a writer, E. V. Wright, was able to construct a 267-page novel in which the letter "e" never once appeared), and this knowledge further reduces "surprise" in text, decreasing the amount of information it bears. The maximum uncertainty (and hence information gained upon reading) would result from an uncorrelated text with each symbol having the same frequency. But then this would not be English and, moreover, in the absence of rules, would bear information but be, in general, short on meaning. The minimum information case would be where only one symbol was repeated endlessly.

Shannon conducted some experiments on how well people were able to predict text based on what had gone before and concluded that English text actually carries about 1 bit per symbol, considerably less than the unconstrained estimate.

If similar constraints could be found to exist in the "text" of Voyager imaging, then the information content would be less than the 5 million-plus bits per picture, and advantage of this might be taken to reduce the load on the telecommunications link to Earth.

There are no rules of spelling or grammar perceptible in a Voyager image, but experience with space (and terrestrial) photography shows that the brightness of a visual scene generally varies in a continuous fashion; there are relatively few points in the picture where brightness jumps abruptly. Sudden transitions might occur at the boundary points of planetary disks or rings.

Hence, as one traces the brightness of the image while moving along one of the 800 lines of (800 per line) pixels, the brightness (one of 256 levels) of a pixel tells us something about the

probable brightness of the next pixel in the line. Voyager engineers were able to take advantage of this fact by encoding and transmitting the *difference* in brightness from one pixel to the next on a line, along with the absolute brightness of the first pixel in the line. Since, as noted, the differences, like the symbols of English text, were correlated, less information needed to be coded and sent to Earth. In this way, over twice as many pictures per unit time could be sent to Earth during the Voyager/Uranus encounter, for which this "image data compression" technique was developed.

Information measures are probably best appreciated and a sense developed for them by noting some numerical examples from the domains of generation, transmission and storage.

While at Jupiter, the two Voyager spacecraft were each able to return up to 115.2 kilobits per second of data, and from nearby Venus Magellan will return data from its radar survey of the planet at 268.8 kilobits per second. The Infrared Astronomical Satellite (IRAS) pumped data to Earth in 1983 at a rate of 1,000 kilobits per second as it flew only 900 km over the tracking station at the Rutherford Appleton Laboratory in Oxfordshire. The first NASA interplanetary spacecraft, Mariner 2 to Venus in 1962, had a data rate of only 33-1/3 bits per second. Not until 1969 were higher rates employed (16.2 kilobits per second) with the Mariner 6 and 7 flybys of Mars. Ample data rates plus the introduction of reprogrammable onboard computers (also for Mariners 6 and 7) ushered in the modern interplanetary spacecraft.

As we saw before in the case of English text, simple quotation of numbers of bits can be misleading if the structure of the material being measured is not taken into account. It has been estimated that the raw processing rate of the human brain is an enormous number: 10^{15} bits per second. But at the creative level of the human brain, if that 2.66 million bit book we mentioned earlier took one year to write, the associated production of information would average less than a tenth of a bit per second. Voyager's central computers process a load of sequenced commands at an average rate of a few tenths of a bit per second in the busy day or two around encounter with a planet.

Entering the realm of superlatives, it has been calculated that the maximum theoretical rate of processing that a computer could achieve is bounded above by 10^{96} bits per second: a rate that will never be achieved or even approached.

Numerical examples of storage capacities include the almost 75 kilobits in each of Voyager's two central computers. A central computer in the Mars Observer spacecraft (1992 launch) checks in at somewhat over 2,000 kilobits. A major architectural difference between the older Voyager data system and the newer one on Mars Observer is the existence of "smart" instruments onboard the latter; programmable microprocessors may exceed the central computer in capacity.

Capacities of ground systems can be very large, "virtually unlimited" as the phrase goes. But there is a limit. Using thermodynamic relations between mass and information, it has been calculated that the information content of the visible universe is approximately 10^{98} bits. Again, the power of structure becomes apparent when we compare this huge number with the 10^{13} or so bits in a large library (this is also about the capacity of the human brain). Some of the disparity between the raw bits in the universe and our knowledge of the universe, as contained in, say, the Bodleian library in Oxford, is accounted for by our ignorance. But an optimist would believe that a large part of the difference has been bridged by the synthesizing properties of scientific theories, just as grammar and spelling organise English text. What do you think? Take as many bits as you like to formulate your answer.

Science Seeds

Ross Jones got a pleasant surprise at the AIAA Aerospace Sciences meeting in Reno last January: people listened to him. With the full crop of ideas for advanced missions that emerge each year in the community, it is not easy for any one proposal to receive proper attention. Jones, a member of the technical staff in JPL's Spacecraft Systems Engineering Section, has outlined a concept that encompasses the electromagnetic launching from low-Earth orbit of small scientific spacecraft whose mass would be in the one to 5 kg range. Such microspacecraft could conduct missions of focused scientific content, enabling many launches per year instead of the stretched-out program which has been the norm for the last decade.

Jones contrasted the press coverage that his recent paper stimulated with the low-key development cycle he has pushed since the idea occurred to him in 1982. At that time, when he saw the electromagnetic railgun proposed as a launcher, he envisioned its use for scientific exploration of the solar system.

The idea of electromagnetic launchers is not new and is a relatively mature technology. Railguns are one member of the class, and Jones selected this mode since extensive development of these devices is now taking place in conjunction with the Defense Department's Strategic Defense Initiative.

Railguns exist now and have been used to accelerate several grams to speeds of almost 10 km/s. In an experiment in 1984, 0.32 kg was accelerated to 4.2 km/s. The method relies on accelerating the object to be launched by an enclosed, expanding plasma at its rear. The object is contained between two rails and an electric current is sent along one rail, then through the plasma, and down the other rail, to obtain the expansion effect. A railgun deployed in Earth orbit as a launcher would be between 50 and 100 m in length. Accelerations during launch would range from 50,000 g to 100,000 g (1 g equals the acceleration due to gravity at the Earth's surface), a factor of ten greater than those imposed on artillery shells.

The term "microspacecraft" has been applied to vehicles in the 20 to 30 kg class (see the May 1985 edition of this column for James Burke's ingenious designs and his article in the July-August 1985 ***Spaceflight***), and Jones has used it for his vehicles, which are actually about one thousandth the mass of typical interplanetary spacecraft. Early in the space age the Sputniks, Vanguards, and Explorers were of small mass, and TRW built 0.7 kg Tetrahedral Research Satellites which were launched in 1963. But today's microelectronics and miniaturisation advances in propulsion systems yield new promise for this class of vehicle.

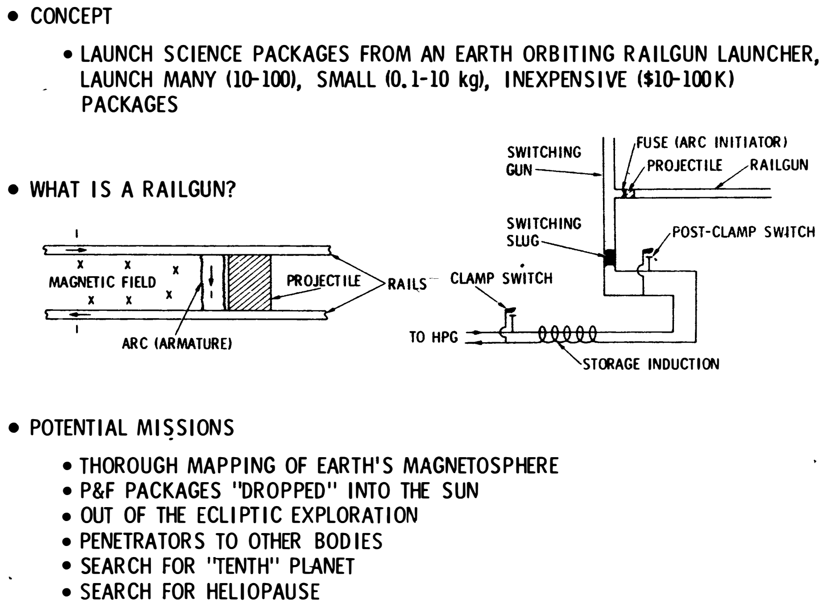
Three engineering subsystems are of particular concern for any microspacecraft: telecommunications, power, and propulsion.

Data could be returned through a radio or optical communications link. Using the Ka band of the radio spectrum and 1 W of power, 10 bits per second could be returned to a 70 m antenna of the Deep Space Network from a distance of 4 AU (600 million km). An optical link could support 200 bits per second as far away as 100 AU.

For a microspacecraft, primary power would most conveniently be supplied by an RTG such as employed on Voyager, but Burke has considered small solar arrays for this purpose. With only low levels of power available from either source, a battery could be useful to store energy for use in supporting a burst mode of transmitting data to Earth.

A "breadboard" of a microspacecraft propulsion subsystem has been built and tested. This breadboard has a diameter of 15 cm, was designed to survive a 100,000 g launch, and give a microspacecraft a respectable 1 km/s velocity change for the purpose of trajectory shaping during the mission.

If the idea of a microspacecraft now seems more feasible, it still remains to be investigated whether there is useful scientific employment for this type of vehicle. The answer depends on what sensors a small spacecraft is capable of carrying and to what places they can be delivered.



Electromagnetic railgun launchers deployed in low-Earth orbit may someday be used to launch kilogramme-sized scientific satellites for specialised missions of solar system exploration. *NASA/JPL*

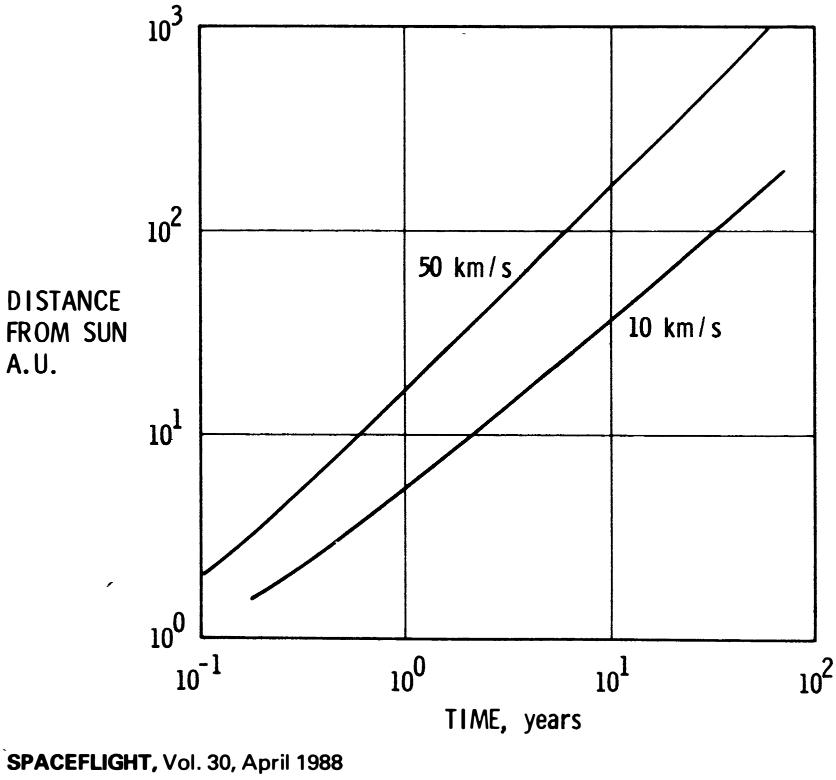
Potential scientific instruments identified by Jones include: imaging devices, cosmic-ray detector, dust detector, energetic-particle detector, magnetometer, gamma-ray spectrometer, and neutral and ion particle detectors. While progress still needs to be made in mass reduction for the instruments in these categories, miniaturisation trends are evident; a 400 gm magnetometer exists and a 25 gm CCD-based video system is commercially available.

Electromagnetically launched microspacecraft would be able to carry one or two small instruments into interplanetary space for the purpose of carrying out any of a large variety of missions. For example, one could conduct gravity-wave investigations, characterise solar system dust, image asteroids and comets, and study the fields and particles properties of the heliopause (the region surrounding the solar system that marks the terminus of the influence of the solar wind).

Thus, one could say that science seeds were planted in the solar system from which a rich harvest of data would be gathered.

The intent of opening discussion on electromagnetically launched microspacecraft is, according to Jones, not to present a finished concept – clearly, work still needs to be done to bring it to fruition – but rather to begin a dialog within the scientific and engineering world and see where it leads. The payoff could be the establishment of a new avenue for the attainment of space science objectives using missions with a high value-to-cost ratio.

Kilogramme-sized spacecraft ejected from Earth orbit at various speeds supplied by electromagnetic launchers could cover large distances relatively rapidly. Many current interplanetary trajectories, designed for more conventional-sized spacecraft, feature long transit times due to the need for planetary gravity assists prior to encounter with the target body. *NASA/JPL*



Space Shuttle Crew Named

The crew for space shuttle mission STS-28, currently targeted for late 1988, will be commanded by Col. Brewster H. Shaw (USAF). Pilot for the mission will be Cdr. Richard N. Richards (USN). Cdr. David C. Leestma (USN), Lt. James C. Adamson (USA), and Maj. Mark N. Brown (USAF) have been assigned as mission specialists.

Shaw has flown previously as pilot on STS-9 and as commander of 61B. Leestma has flown previously as a mission specialist on mission 41G.

Richards, Adamson and Brown will be making their first shuttle flight.

STS-28 will be a US Department of Defense mission aboard the orbiter Columbia.

New Space Policy

A revised national space policy that will set the direction of US efforts in space for the future was approved by President Reagan on January 5, 1988.

The policy is the result of a five month inter-agency review which included a through analysis of previous presidential decisions, the National Commission on Space report, and the implications of the space shuttle and expendable launch vehicle accidents. The primary objective of this review was to consolidate and up-date presidential guidance on US space activities, providing a broad policy framework for the future.

The programme has three major components:

- Establishing a long-range goal to expand human presence and activity beyond Earth orbit into the solar system.
- Creating opportunities for US commerce in space.
- Continuing national commitment to a permanently manned space station.

A major new technology programme, "Project Pathfinder", will enable a broad range of manned or unmanned missions beyond the Earth's orbit.

This research effort will develop United States know-how in several important areas, such as humans in the space environment, closed loop life support, aerc braking, orbital transfer and manoeuvring, cryogenic storage and handling, and large scale space operations.

However, there is no reference to specific goals such as missions to the Moon or Mars.

The new policy emphasises three US space sectors: national security, civil governmental and commercial. Close cooperation between all three will be needed to avoid duplication of effort.

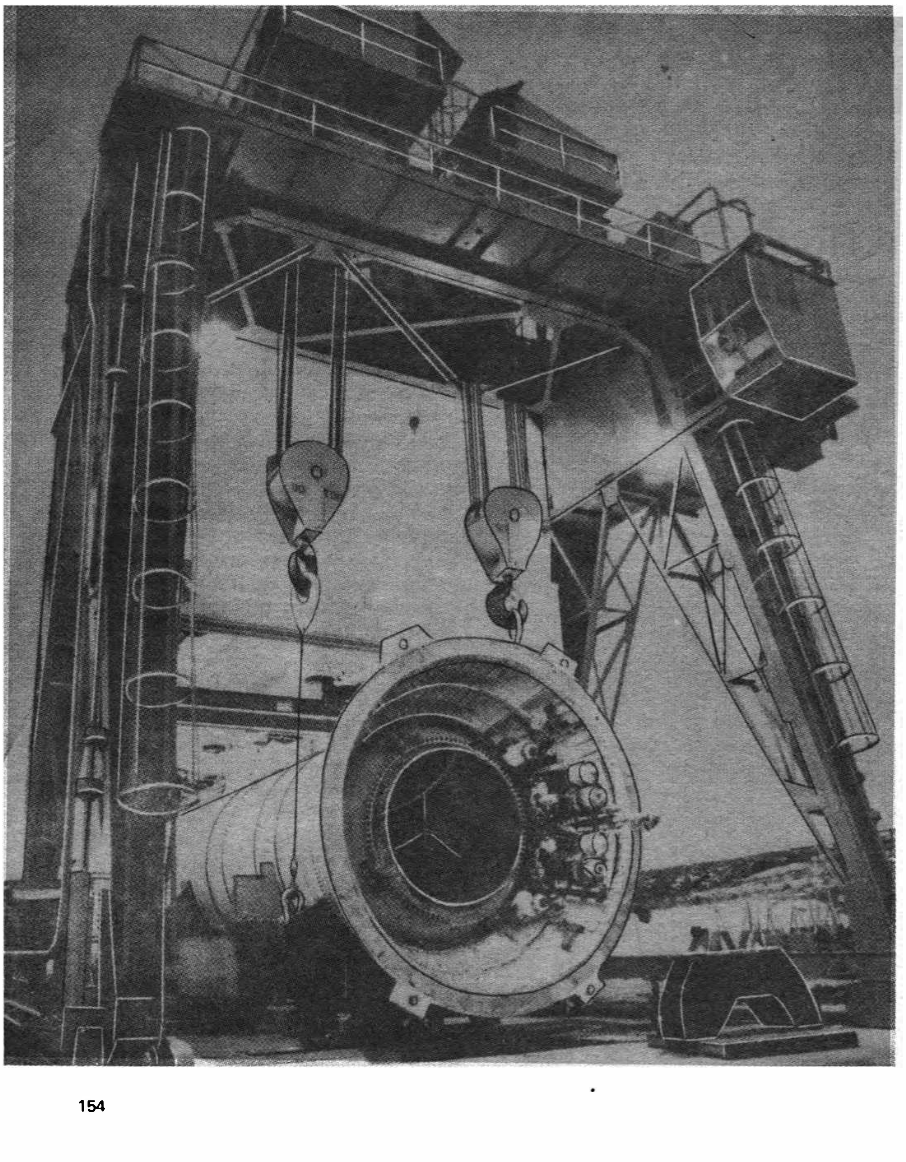
One of the inter-sector policies concerns the creation of space debris (***Spaceflight***, January 1988, p.4) with the design and operation of space tests, experiments and systems striving to "minimise or reduce accumulation of space debris".

Support for a permanent manned presence in space from the mid-1990's is reaffirmed with Congress being asked to make a three year space station funding commitment (starting in Fiscal Year 1989) of $6.1 billion.

Prior to the space station becoming operational a commitment is given to fly the Spacehab pressurised module (see p.138) in the early 1990's. However, the policy statement did not contain a reference to the Industrial Space Facility, the man-tended free-flying laboratory being developed by Space Industries Inc., although the government is required to lease space as an "anchor tenant" in such a facility that is "financed, constructed and operated by the private sector".

There is also official encouragement for putting expended shuttle external fuel tanks into orbit, for uses such as research, storage or manufacturing in space. Such suggestions have been made for years, but until now they have all been rejected on cost or safety grounds (***Spaceflight***, March 1988, p.95).

Assembly of aft skirt to a space shuttle solid rocket booster in preparation for a static test firing at Morton Thiokol's test plant in Utah. Testing and refurbishment work is currently on schedule for a launch on August 4 but NASA is remaining cautious – modifications to the orbiter Discovery to be used on STS-26 are at a critical stage with only seven contingency days in the schedule.



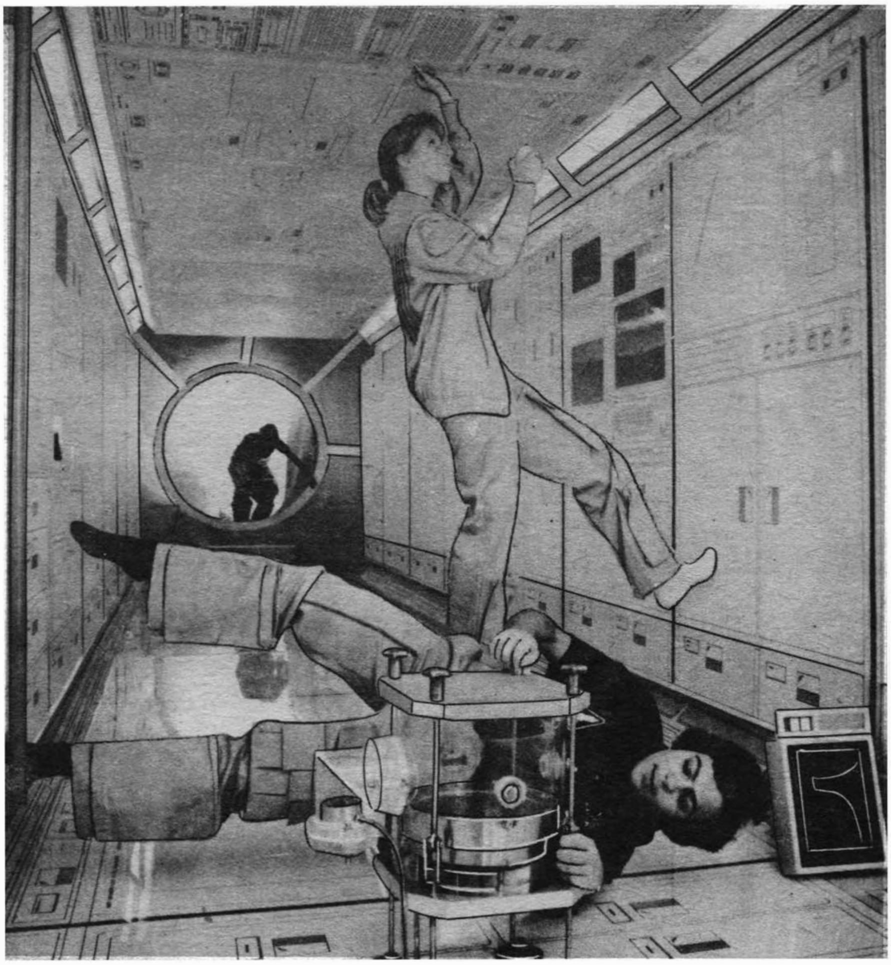
NASA Budget Increased for FY 1989

President Reagan's Fiscal Year 1989 budget gives NASA what is needed to carry out on-going programmes in space and aeronautics and to take the essential next steps to assure future United States' leadership in space, according to a statement issued by NASA administrator, James C. Fletcher.

The Fiscal Year 1989 NASA budget of $11.5 billion is a substantial increase over the amount appropriated for NASA in Fiscal Year 1988.

There are two main reasons. Firstly, the space shuttle will be flying again during Fiscal Year 1989 after a long hiatus. NASA will have to meet the costs of building the flight rate up to approximately seven missions in Fiscal Year 1989 and to 10 missions in Fiscal Year 1990.

Secondly, the international space station will be moving into full-scale hardware development. The FY 1989 budget provides the normal build up in funding required in the second year of a major development programme.



Lockheed engineers inside a mock-up of the life sciences portion of the international space station's United State's Laboratory Module simulate weightlessness as they check the fit and placement of equipment. A team-mate of Boeing, which is the NASA prime contractor for Work Package 1, Lockheed will outfit the life sciences area and integrate human and animal research payloads and the Health Maintenance Facility. Lockheed is also a team-mate on other work packages with McDonnell Douglas and Rocketdyne.
Lockheed

It also recognises that these "built-in" increases are essential to carry out the national commitment to return the space shuttle to flight and to carry out the President's recommendation, now approved by the Congress, that the United States should proceed with the development of a permanently manned space station, said Dr. Fletcher.

The NASA budget also reflects the high priority given by the President in his Fiscal Year 1989 budget to science and technology generally. The NASA FY 1989 budget therefore carries forward a robust programme in space science, including:

1. Preparing major astronomy and planetary missions for launch when the shuttle is ready.
2. Providing expendable launch vehicles for a number of future science missions.
3. Initiating a major new "Great Observatory" project, the Advanced X-Ray Facility (AXAF).

The budget provides for major advances in technology, including development of a new Advanced Solid Rocket Motor (ASRM) for the space shuttle system; continuation of the expanded Civil Space Technology Initiative (CSTI) begun in Fiscal Year 1988; and a strong, continuing programme in aeronautics.

According to Dr. Fletcher, this support for science and technology is one of the most significant priorities in the President's Fiscal Year 1989 budget. "It reflects a recognition of the realities of the crucial roles of science and technology to the nation's future. This is clearly not the time to 'freeze' or cut back in this vital area," he said.

Significantly, the Fiscal Year 1989 budget supports the President's new National Space Policy which clearly commits the United States to space leadership as a fundamental national objective. The policy establishes that, for the first time, the United States has a long-range goal of expanding human presence and activities beyond Earth orbit into the solar system.

In support of this long-range goal, the budget includes $100 million for starting a "Pathfinder" programme of detailed studies and technology development to provide a sound basis for future decisions on approaches and missions to move human presence and activities beyond Earth orbit into the solar system.

Another important aspect of the President's National Space Policy to which NASA will be giving direct support in Fiscal Year 1989 is the expansion of the private sector role in space.

"NASA will procure its needed Expendable Launch Vehicle (ELV) services commercially from the private sector whenever possible. We will continue our programmes to encourage and work cooperatively with private business concerns wishing to undertake enterprises in space," said Dr. Fletcher.

"As a specific undertaking, NASA will offer on a competitive basis to lease a major portion of a commercially developed space facility to be built by a private company for microgravity research and manufacturing."

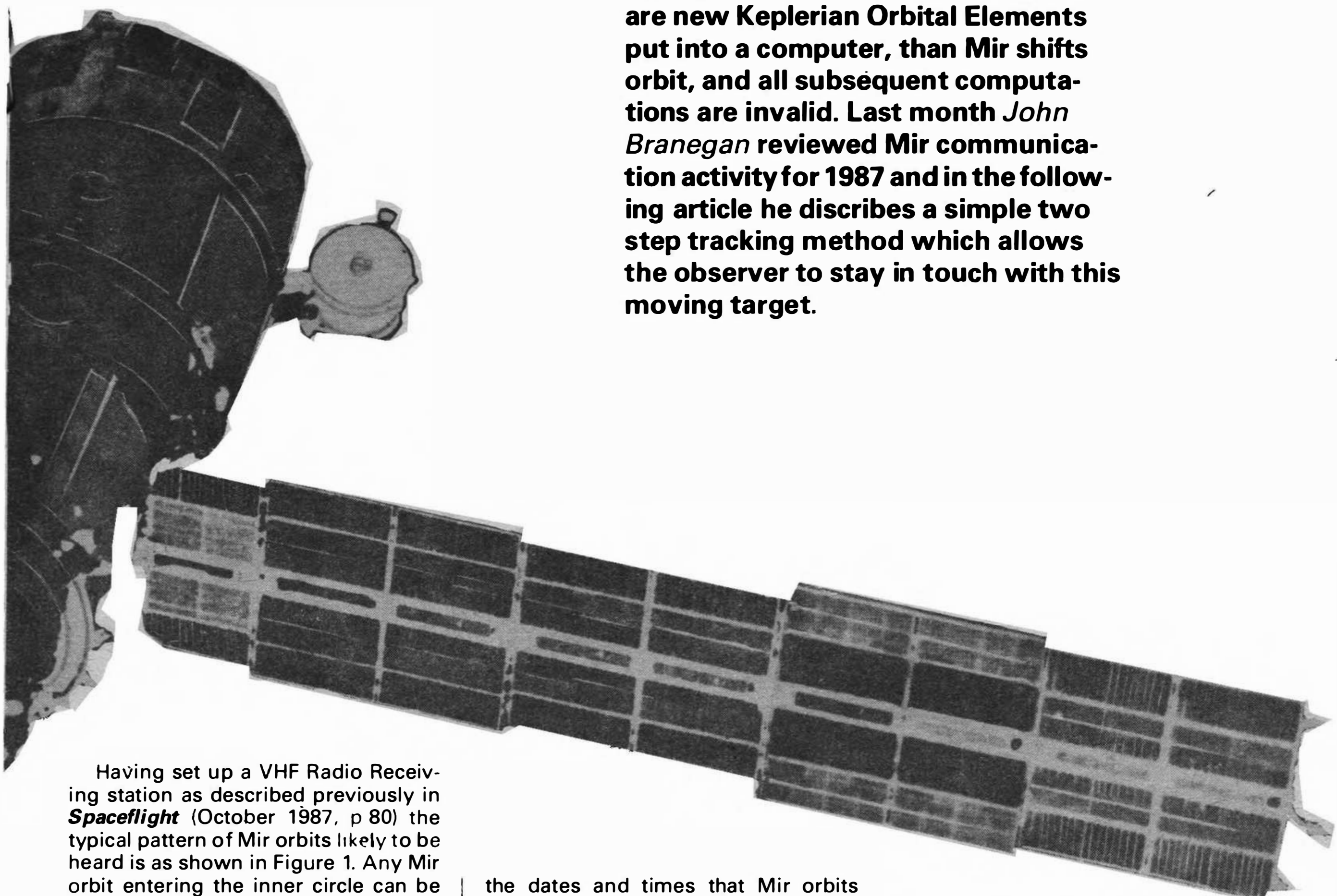
Keeping

Track of Mir

by John Branegan

(156)

Mir cannot be treated as an ordinary satellite because it is constantly using its engines to alter its orbit. No sooner are new Keplerian Orbital Elements put into a computer, than Mir shifts orbit, and all subsequent computations are invalid. Last month *John Branegan* reviewed Mir communication activity for 1987 and in the following article he discribes a simple two step tracking method which allows the observer to stay in touch with this moving target.



Having set up a VHF Radio Receiving station as described previously in ***Spaceflight*** (October 1987, p 80) the typical pattern of Mir orbits likely to be heard is as shown in Figure 1. Any Mir orbit entering the inner circle can be heard in the UK if the cosmonauts transmit on their 143.625 MHz FM downlink. A pattern of five consecutive orbits audible at roughly 95 minute intervals is possible, the first orbit in range passing south east of the UK, the next 95 minutes later passing southwest to east along the English Channel followed by a third again 95 to 96 minutes later passing almost west to east again along the South Coast. On these three orbits Mir usually communicates with Soviet Ground control just after it has passed east of London. On the last two orbits (Nos. 4 and 5) Mir passes southwest of the UK. Contacts with the USSR are fleeting and infrequent on these orbits, but if Comships are present off Sable Island east of Canada or near the Canary Islands Mir may be heard in the UK as it talks to them.

Prediction of Mir Orbit Timings and Tracks

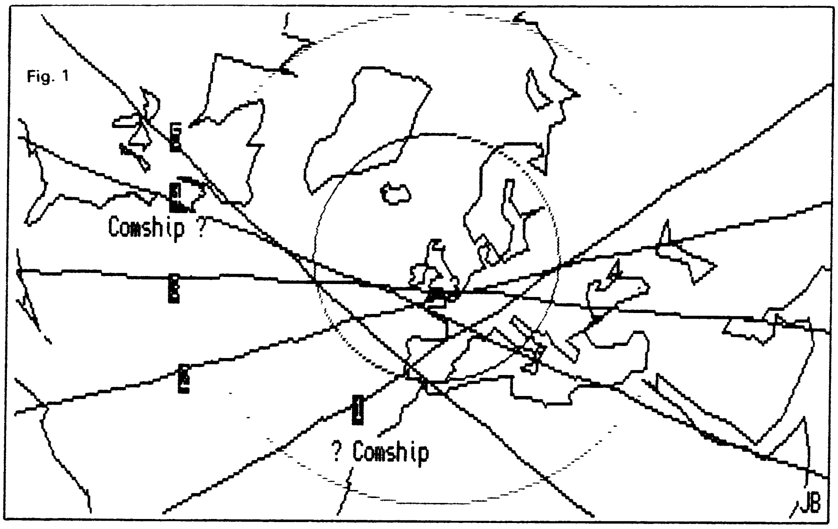
Figure 2 shows a graphic chart of the dates and times that Mir orbits were heard by a UK station between October and December 1987. Points to note are:

(i) The parallelogram window block of orbits heard in the UK repeats roughly every 59 days, because Mir's orbital plane rotates a full circle in that period. This orbit window timing is not seriously disturbed by changes in Mir's orbital height so it can be used to predict when future orbit windows will occur, up to several months ahead.

(ii) The cosmonauts rest and sleep from about 2000 UT/GMT to 0500 UT/GMT. They may be heard now and again between 2000 and 2100 UT, but they never transmit between 2100 and 0500 unless there is something unusual happening, such as a docking.

(iii) Actual times at which Mir was heard are indicated on Figure 2 by small circles. To get exact dates and times, read the vertical date column to get the date you want then move horizontally to your right along the 24 hours of the day until you reach a circle. You can read off the time of day by moving vertically upwards until you meet the horizontal time column.

For example, the first event in the window frame is at its top right corner and records an orbit heard at 1943 UT on October 10, 1987. The next event heard was at 1844 on October 12, 1987. By October 28 the window was broad enough to hear five orbits but only the first three were heard, at 1325, 1459, and 1633 UT. The two westerly orbits (four and five on Figure 1) were not heard that day. The last event heard in the window in Figure 2 was at 0556 UT on December 2, 1987. There was then a gap of several days before the first orbit of the new window was heard at 2000 UT on December 9.



Mir space station – sequence of five consecutive orbits in range of the UK (orbit sequence Nos are shown on tracks as they approach UK Air Space).

Predicting the Dates of Future Windows

The spacing of windows can be as little as 58.2 days when Mir is at low altitude around 320 km height, or as much as 59.6 days when Mir is orbiting up at 375 km. This is averaged as 59 days and four succesive windows are predicted on Figure 3, which has the same general form and scale as Figure 2 but has its time axis shifted to the right in order to accommodate lists of window dates at four day intervals up to October 1988.

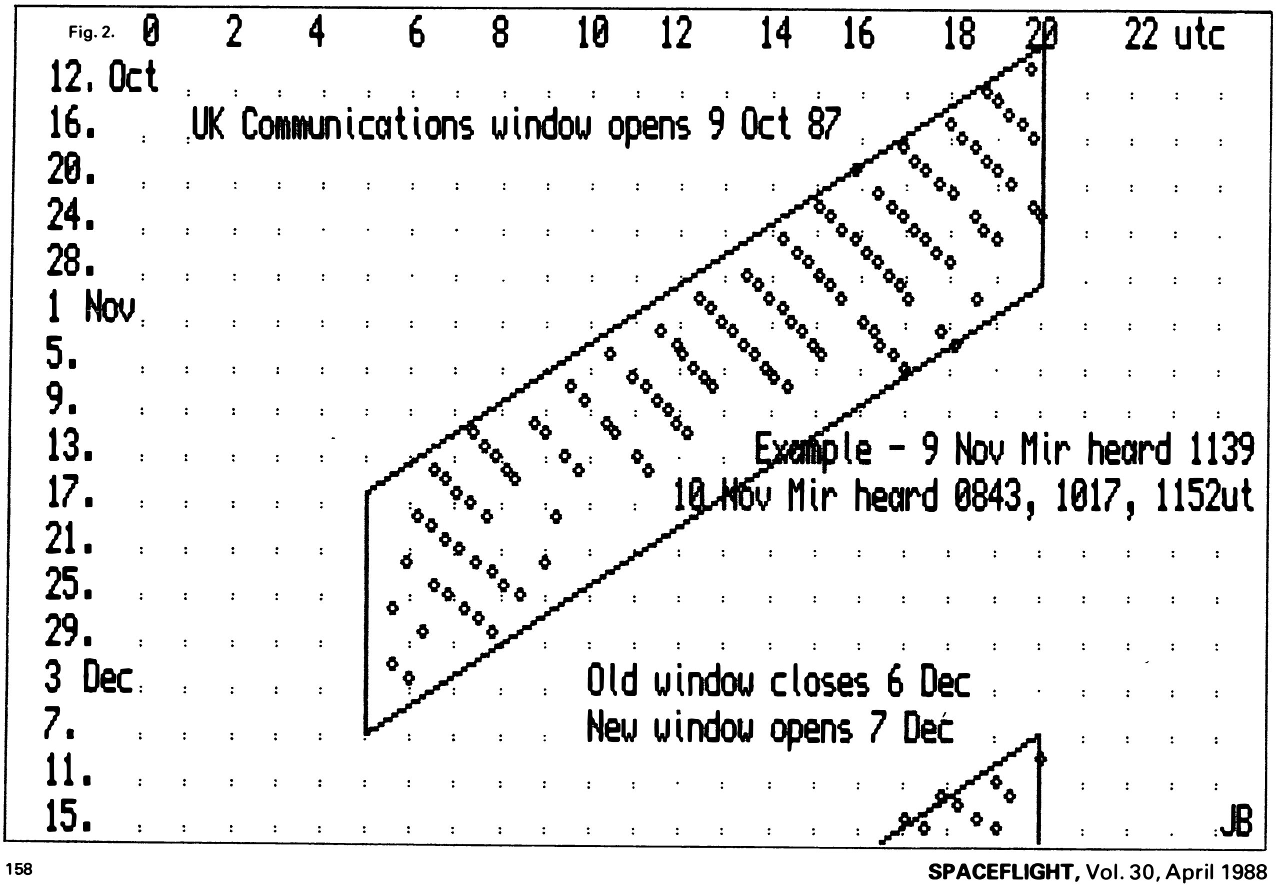
Using Figure 3 it is evident that new windows open late in the evenings of February 4, April 3, and June 1 of 1988 with an orbit south east of the UK (No. 1 of Figure 1). Old windows close with one last (No. 5 track of Figure 1) orbit at just after 0500 UT on or about April 2, May 31, July 29 and September 26, 1988.

Worked Examples

From Figure 3 it is possible to predict roughly when Mir will be heard in the UK, and what track it will follow relative to the UK. For instance, on July 6, the Mir window opens for UK listeners just after 0600 UT (add one hour for British Summer Time) and closes at about 1400 UT. All the five orbits shown in Figure 1 may be heard starting somewhere in the first 90 minutes of the window with an orbit along track 1 of Figure 1 tracking southeast of the UK, followed thereafter at roughly 95 minute intervals by orbits near tracks 2 to 5 respectively of Figure 1.

Consider a Mir observer who can listen all day on March 22, 1988. From Figure 3 he can expect a maximum of three orbits in the window, following tracks 3, 4 and 5 of Figure 1 at roughly 95 minute intervals between 0500 and 0930 UT. The earliest of these orbits follows track 3 and usually produces communications with the USSR. By contrast the succeeding orbits following tracks 4 and 5 are only rarely heard calling the USSR. They can, however, sometimes be heard calling Comships present either off Sable Island, Canada or the Canary Islands. Indeed as Figure 2 shows these orbits on tracks 4 and 5 did produce communications with one Comship up to November 5, 1987, and to another Comship, possibly off the

Kettering Plot showing Mir communications window shifting from late pm to early am October to December 1987 (UTC). Note: Radio signals are rarely heard between 2100 to 0500 UT.



SOVIET SCENE

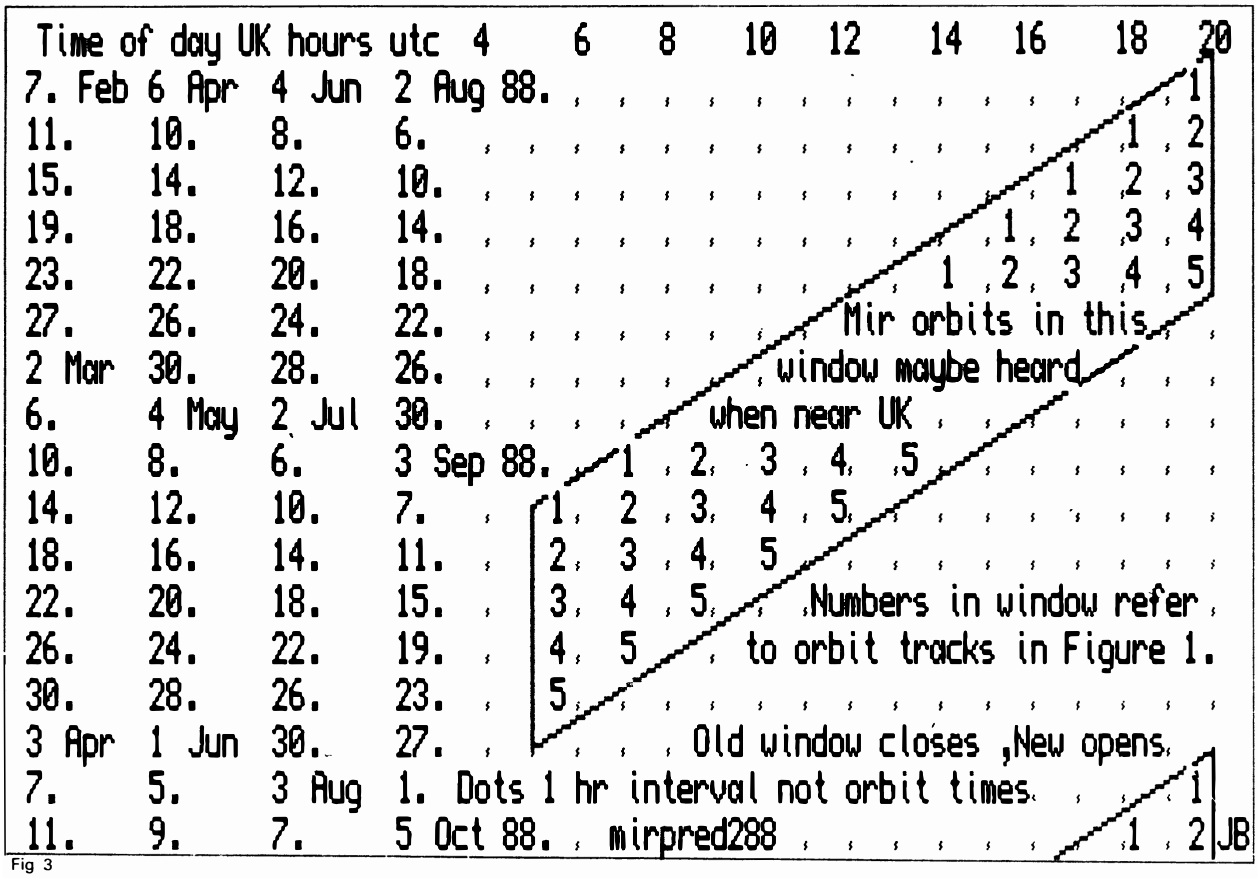


Fig 3

Predicted UK–Mir communications windows February to September 1988 143 625 MHz FM signals heard 2100 to 0500 UT, at special times only (eg Docking)

Canary Islands from November 22, onwards.

A quite different example occurs on June 4, 1988. Using Figure 3, the window is shown to be open only briefly from about 1830 until the cosmonauts close down for the night around 2000 UT. In this situation the Mir listener in the UK may catch one Mir transmission as it tracks along track 1 of Figure 1 sometime between 1830 and 2000 UT. Listeners would be advised not to switch off at 2000. The remaining orbits along tracks 2 to 5 all come near the UK and the cosmonauts do occasionally transmit between 2000 and 2100 when Mir is passing the UK in the evenings. No transmissions should be expected after 2100 UT (2200 BST) unless there is some special reason, such as a manned docking, and in this case the transmission is more likely to be at around 0400 when the Asian USSR is already sunlit and would permit safe landing in the event of a docking abort.

Using Figure 3 this way, it is possible to estimate when Mir will come in range of the UK and what track it will follow.

Then, having found a Mir orbit, the listener can expect a repeat every 95 minutes thereafter until the window closes. Equally important, as the following paragraphs explain, is logging the time Mir is heard one day because there is a good chance it will be heard again the next day, between 14 and 28 minutes later.

Regular Prediction of Mir Orbit Times

Table 1 shows a list of times when Mir was heard in Scotland in November 1987. Please note the third column of this table, which records the time shift between one day's orbits and the next day's orbits.

Figure 4 shows why this time shift from one day to the next is important. Mir is following almost a fixed track in space. So if Mir is at point =>, one day, it will be back near this same point on its track 16 whole orbits later.

This means that Mir will be at point =>, 16 orbit periods later. So if Mir is at say 320 km mean height, and has an orbital period of 90 87 minutes in consequence of that height, it completes 16 x 90.87 minutes, equalling 1454 minutes, which is one day plus 14 minutes.

In the same, roughly 24 hour period, the Earth with the listener's home station on it has rotated a full circle inside Mir's orbit. As Figure 4 shows this has

Table 1 Times when Mir was heard over Scotland in November 1987

Date	Times UT/GMT				Mins later/day
8th	0950	1124			
9th	1139				15 (Height about 320 km)
10th	0843	1017	1152		13
11th	0722	0857	1031	1206	14
12th	0737				15
13th	0750	0923	1100		13
14th	0630	0804	0940	1114	14 17 14
15th	0643	0818			13 14
16th	0659				16
17th	0718				19 (Height move to 340 km)
18th	0605	0739	0912		21
19th	0624				19
20th	0645				21
21st	0704				19

Table 2. Mir space station period, height and next day timing.

Orbit Period	Mean Height	Next Day Timing (later by)	Remarks
90.9 minutes	323 km	14.4 minutes	Lowest operational
91.0	328.2	16	height ready for
91.1	333	17.6	Soyuz docking.
91.2	338	19.2	–
91.3	343	20.8	Rough Soyuz max. op. height
91.4	348	22.4	–
91.5	353	24	Mir regular cruising height
91.6	358	25.6	
91.7	362.7	27.2	–
91.8	367.5	28.8	–
91.9	372.45	30.4	
92.0	377.35	32	

Note: Mir's actual orbit is usually slightly elliptical but for simple tracking purposes it can be regarded as circular.

the effect of bringing Mir in range of the listening station every one day plus 14 minutes.

Given this information, an operator who builds up a log of times Mir is heard as in Table 1, can use this knowledge of *minutes later per day* to predict when Mir will be heard on subsequent days.

This is all straight forward until Mir fires its engines as is clearly shown by the Table 1 log after November 16. The minutes later each subsequent day has changed to a mean of about 20 minutes per day. Table 2 shows what this actually means in terms of Mir's orbit. From Table 2 it is clear that Mir was at a mean height of about 320 km up to November 15. This is usually the bottom limit for Mir. Left alone it would suffer more and more atmospheric drag and quickly get dangerously low in height. So it was no surprise that Mir used its engines or those of an attached Progress supply module to lift itself to a more comfortable height on or about November 16. Table 2 shows that the new 20 minute mean interval of Table 1 after November 16, was the result of a height shift up to about 340 km.

The above example shows how Figure 3 'Mir orbit window' and Table 1 'Mir times heard log' can be used to keep track of Mir, in regard to both when to listen and what track Mir is on when heard.

Less obvious but equally useful, this combination of data tells the listener what mean height Mir is orbiting at, allowing judgements as to when Mir will next use its engines, so that listeners can begin to not only predict tracks and times heard, but also predict when timings are likely to change. In this regard it was interesting to note that even after November 16, 1987, Mir was not at its regular mean cruising height of 350 km (with a roughly 24 minute day to day shift). So it was no surprise, when, in early December Mir fired its engines again and took up its usual cruising height of 350 km, a shift which was signalled to listeners by a change to a 24 minutes per day shift.

Mir Tracking Rules

(i) Mir comes in range of the USSR and can be heard by UK stations as it talks to ground control, at roughly 95 minute intervals. Mir transmits on 143.625 MHz FM voice and also uses a Beacon on 166.125 MHz.

(ii) Mir makes 16 orbits of the Earth in a little over one day. A sequence of five of these orbits may be heard in the UK, making a pattern of five transmissions 95 minutes apart in a 6 hour 20 minute period. Then, for the remaining 17 hours 40 minutes of the day UK listeners cannot hear Mir.

(iii) Mir's 16 orbits per day take 1454 to 1468 minutes to complete, depending on orbital height. So Mir appears on successive days between 14 and 28 minutes later in time, each successive day.

(iv) Mir's orbit slips about 6 degrees West each day, because of perturbation due to Earth oblateness. The difference between Earth Mean Sun Time and Sidereal "Space or Star" Time. This has two effects. Firstly, the five orbit in-range sequence jumps one orbit earlier every three and four days.

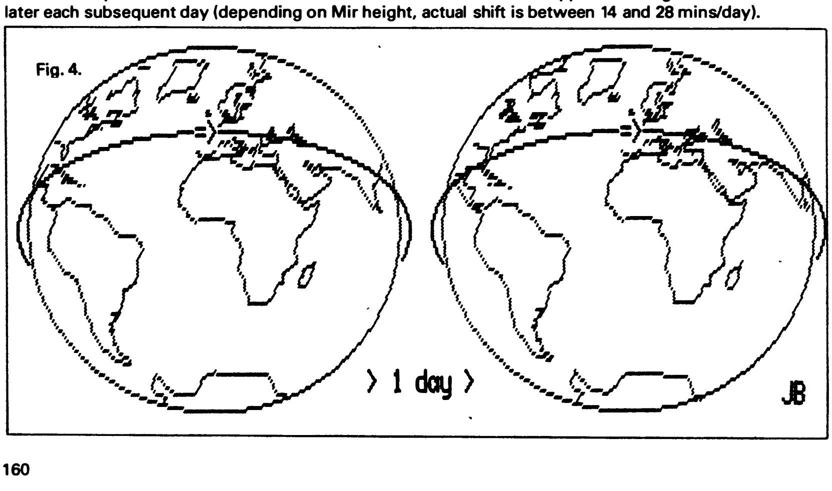
Secondly, because of this shift in Mir's orbital plane, the whole five orbit in-range sequence drifts earlier passing through a full 24 hours every 59 days, thereby producing the gradual slope of the Figure 2 and Figure 3 windows.

(v) The cosmonauts sleep from 2000 UT to 0500 UT. This has two effects. Firstly, if the first orbit you hear is on track 1 of Figure 1 at or after 1830, you are most unlikely to hear any more orbits that day. Secondly, if you hear an orbit west of UK in the early morning, you have missed the previous orbits because the cosmonauts do not transmit in their sleep period. You are unlikely to hear any more orbits that day because Mir is getting near the end of the 59 day window and you must start planning to shift your listening watch from early morning to late evening, ready for the opening of a new window.

(vi) The method outlined in this paper is crude but effective. It can be used on its own to track Mir or it can be used in conjunction with the predictions from a microcomputer using suitable software and NASA NORAD two-line Mir Keplerian Orbital Elements. This method is based on the simple but highly effective satellite timing plots developed by *Geoffrey Perry* and the *Kettering Group*.

The Earth and Mir, from one day to the next. The Earth spins roughly one revolution in a 1440 minute day and Mir completes 16 orbits of 90.87 minutes in 1454 minutes. So Mir appears in range of UK 14 minutes later each subsequent day (depending on Mir height, actual shift is between 14 and 28 mins/day).

Fig. 4.



Satellites Lost After Proton Launcher Fails

Soviet attempts to market an international launch service using the Proton rocket have received a further set-back following the launch failure on February 17.

The SL-12 Proton booster, at present the largest fully operational rocket in the world, was attempting to launch a triple payload of Glonass military navigation satellites.

A malfunction prior to fourth stage ignition resulted in the vehicle reaching an altitude of only about 100 miles (intended operating orbit around 12,000 miles above the Earth) before it fell back into the atmosphere and burnt up.

This was the third Proton failure in 13 months. On April 24 last year a similar payload of three Glonass satellites failed to reach the correct orbit after premature shutdown of the fourth stage.

On January 30, 1987 another fourth stage malfunction caused the loss of a communications satellite which should have been propelled into geostationary orbit.

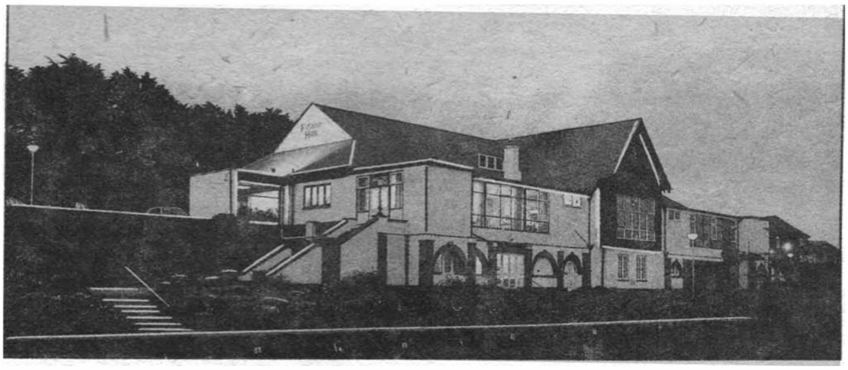
Another major space loss for the Soviets occurred earlier this year on January 31, after a commerical imaging spacecraft went wrong.

The vehicle, designated Cosmos 1,906, was launched on December 26 and would have normally been recovered on Earth after two weeks.

However, after it malfunctioned Soviet controllers blew it up on January 31 to prevent it making an uncontrolled re-entry. Cosmos 1,906 had been destined to return film canisters containing pictures of the Earth for sale by the Soyuzkarta marketing organisation.

Lift-off of a Soviet Proton rocket.

SPACE '88 —



Evening view of Falaise Hall, attractive setting for the Saturday evening banquet

Man in the 21st Century

SPACE '88 **is already shaping up as the major space gathering of the year in the UK, attracting many top people from the world of space.**

Organised by the British Interplanetary Society, this will be the fourth in a series of such pioneering space conferences, the first of which was in 1982.

This year **SPACE '88** is being sponsored by ***Spaceflight*** magazine, recognising the key role ***Spaceflight*** is now playing in developing public awareness to space, both in Britain and internationally.

Several hundred people, from those directly involved in the space business to the pure enthusiast, are expected to gather in the pleasant surroundings of the White Rock Theatre, Hastings, Sussex, for **SPACE '88**, over the weekend of September 29 to October 2.

The theme of **SPACE '88** will be 'Space: Man in the 21st Century' and lectures will be arranged under a number of headings with further details being announced shortly. Accompanying persons will be at liberty to attend any of the conference sessions.

Many of the names familiar to ***Spaceflight*** readers will be at **SPACE '88** as part of an exciting lecture programme now in the final stages of preparation.

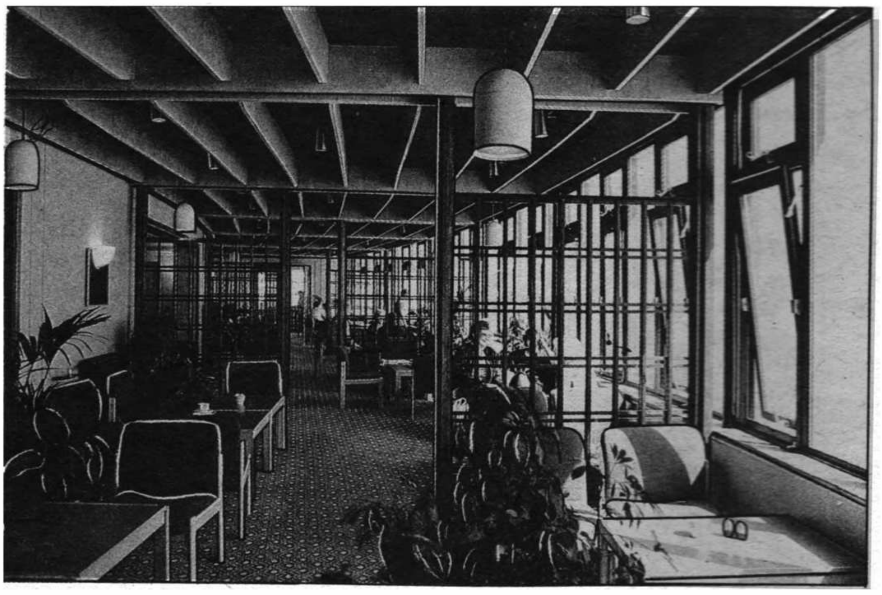
During breaks in the programme those attending will have the chance to chat informally in the pleasant surroundings of the 'buttery' (see picture below) or browse around some of the stands and displays, which will include the new range of Society promotional items and a special ***Spaceflight*** display.

SPACE '88 will be a weekend to enjoy. All participants, together with accompanying spouse or near relative, will be invited to a free welcoming reception on the Friday evening. This will be hosted by the Mayor of Hastings and will include a buffet supper.

On the Saturday evening, activity will transfer to the luxurious surroundings of the nearby Falaise Hall for a Banquet. A delicious meal, including wines, will be followed by topical speeches from space industry guests of honour.

SPACE '88 is a unique chance to become closely involved in the exciting new era of space exploration and exploitation. Send off now for more details and a registration form – please enclose 20p stamp or an international reply coupon.

Informal surroundings of the White Rock Theatre buttery where coffee and tea will be served during morning and afternoon breaks.



Special Discounts for Society Members

SPACE '88 is open to anyone with an interest in space and there are substantial discount rates for all Society members who wish to attend.

The scale of charges, which covers registration, civic reception and dance, and mid-morning and mid-afternoon refreshments, is as follows:-

Non-Members	£55	(US$90)
Society Members	£40	(US$76)
Members under the age of 21	£20	(US$36)
Opening Civic Reception	FREE	
Accompanying Person	£10	(US$18)
Banquet	£22	(US$40)

Several hundred people are expected to attend SPACE '88 and pre-booking, especially if banquet tickets are required, is strongly recommended. Registration forms together with an information pack on Hastings will be sent on receipt of a 20p stamp or an international reply coupon. Please write to SPACE '88, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

Pictures reproduced by kind permission of Hastings Borough Council Tourism and Recreation Department.

The Future Comes to Historic Hastings

Often described as 'a delightful blend of old and new', Hastings has preserved much of its heritage and the old town is a fine example of conservation.

Old, half-timbered houses line the cobbled streets which are over-looked by the ruins of the first Norman castle built in England.

Life in Norman England under the rule of William the Conqueror is the subject of a special 'Doomsday' exhibition on the lower floor of the White Rock Theatre, Hastings, and admission to this will be free to those attending Space '88.

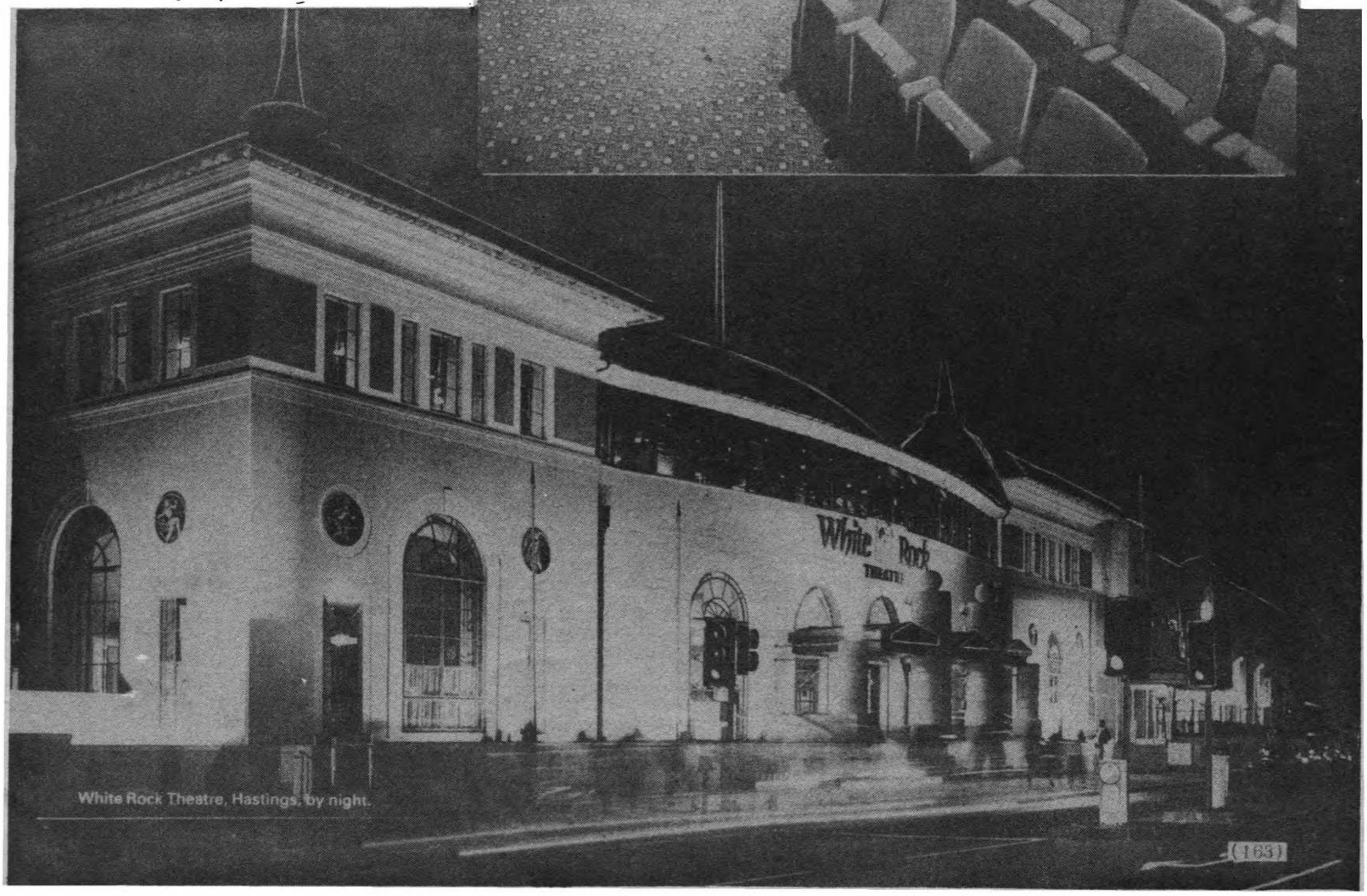
Hastings, located on the Sussex/Kent border overlooking the English Channel to the south, is just 62 miles from London via the A21 which is also linked to the M25.

Frequent fast trains run from two main London Stations, Victoria and Charing Cross, and there are also regular daily coach services from Victoria Coach Station via National Express.

London Gatwick airport, which handles direct flights from all parts of the world, offers a direct rail link with Hastings and the distance by road is approximately 50 miles.

Accommodation in Hastings is both plentiful and varied with many comfortable guest houses and small hotels offering bed and breakfast from as little as £7.50 per night. Full accommodation details will be sent out with all requests for further information and registration forms.

Auditorium (right) for the main lecture programme is spacious and comfortable.



White Rock Theatre, Hastings, by night.

New Society Fund Raisers

The Society has added new items to its growing list of fund raising saleables which now range from space videos and surplus library books to sweat shirts and car badges.

T-shirts, sports shirts and sweat shirts, all bearing a three inch diameter Society logo, are now on sale. Prices are from £6.50 for a T-shirt and £11.50 for a sweat shirt to £14.00 for a sports shirt.

All are of high quality material (50/50 cotton/polyester) and fully machine washable. Postage is £1.00 (UK), or £1.50 (overseas) for single items.

T-shirts, white with a blue logo, can be obtained in the following sizes: 30-32; 34-36; 38-40; 42-44; 46-48; and 48-50. Sweat shirts, navy blue with a red logo, are in the same sizes except 48-50. The short sleeve sports shirt, light blue with navy logo, comes on small, medium, large and extra large. Please enclose cheque with order and remember to state size.

A full list of Society saleables, profits from which go to the Development Fund, can be obtained by sending an SAE to the Society offices. Further adverts will also appear in future issues of ***Spaceflight***.

Spaceflight '88?

The 'announcement' on the front cover of the March issue was made in error due to incorrect information being supplied to our printer. It should, of course, have read: Announcing ... ***Space '88.***

JBIS Electric Propulsion Issue

The April 1988 issue of the Journal of The British Interplanetary Society is to be combined with the May issue.

This special double issue features a selection of papers presented at the International Electric Propulsion Conference in Colorado, USA last spring.

The papers comprise of the majority of European contributions to the Conference – serving to give an idea of the depth and coverage of European electric propulsion activities.

Copies of the ***JBIS***, price £20.00 (US$35.00) to non-members, £8.00 (US$14.00) to members, including post and packing, can be obtained direct from the Society. A full contents listing will be published in the May ***Spaceflight***.

Elections to Society Council

Candidates recently elected to the four vacancies on the Society's ruling Council were G.V. Groves (759 votes), M.R. Fry (675), G.V.E. Thompson (629) and R.A. Buckland (615). The other candidate was D. Baker (533) who had given notice of withdrawal from the ballot after papers had been issued.

A total of 839 ballot papers were submitted up to the deadline of January 31, 1988. None were spoilt. Scrutineers were P.R. Freshwater and E.M. Waine.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

6 April 1988, 7-9 pm — **Film Show**

RETURN TO KENNEDY

The following films will be screened:

Spaceport USA
Doorway to Tomorrow
In the Time of Apollo
The World was There

The meeting will take place in the Society's conference room. Admission is by ticket only. Members should apply in good time enclosing an SAE.

4 May 1988, 7-9 pm — **Lecture**

HISTORY OF THE ROYAL OBSERVATORY

A.J. Perkins

Flamsteed, Halley and Bradley, the first three Astronomers Royal, need no introduction to anyone with an interest in the history of astronomy. The seventh Astronomer Royal, G.B. Airy, has his own renown but his life and work at the Royal Observatory, stretching over 46 years, are not well documented. Tracing the history of the Observatory at Greenwich from its foundation in 1675, Mr Perkins will show in his talk how Airy's achievements and setbacks have affected the development of the establishment up until the present day.

Admission by ticket only. Members should apply in good time enclosing an SAE.

4 June 1988, 10-4.30 — **Symposium**

SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

25 June 1988, 2 pm — **Visit**

RAF Cosford Museum

This will be a special afternoon tour, limited to 25 members. Registration details and further information available from the Society. Please enclose SAE.

6 July 1988, 7-9 pm — **Lecture**

SUPERNOVA 1987A

A.T. Lawton

Members only. Please apply for ticket, enclosing SAE, in good time.

14 July 1988, 10-4.30 — **Symposium**

EXTENDING THE SPACE INFRASTRUCTURE

The reports of the National Commission on Space and Dr. Sally Ride have paved the way for a new innovative space policy in the United States. It encompasses the setting up of bases on the Moon and manned exploration of the planet Mars. The BIS is holding a two part symposium on the issues raised by this exciting new prospect.

The purpose of the symposium is to start European discussion on the subject, including a review of American proposals, and proposals for suitable European contributions to the programme.

The symposium covers the following subjects:
- Infrastructure planning
- Orbital transfer systems
- Geostationary operations
- Lunar transportation system
- Lunar bases
- Planetary exploration systems
- Exploitation of the solar system.

The first part of the symposium will be held on 14 July 1988 and the second part will be held on 15 November 1988.

Offers of Papers are invited
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Society. Please enclose SAE.

17 September 1988, 12 noon — **AGM**

ANNUAL GENERAL MEETING

The 43rd Annual General Meeting of the Society will be held in the Society's conference room on Saturday, 17 September at 12 noon. Details of the Agenda will be published in due course.

Admission is by ticket, available to Fellows only, who should apply in good time enclosing SAE.

30 Sept – 2 October 1988 — **Conference**

SPACE '88

Major weekend space conference, including varied programme of lectures and full social programme.

Venue: White Rock Theatre, Hastings, Sussex, UK

Registration
Forms and further details are available from the Society by sending 20p stamp or international reply coupon.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

CORRESPONDENCE

UK Funding For Space Activities

In the February issue (p.76), Spaceflight ***was privileged to publish Roy Gibson's own account of recent events in the European space community and their effect on Britain's position and future prospects. UK readers in correspondence with their MP's about the lack of Government commitment to space have taken up the points made in Roy Gibson's timely authoritative account. We quote from two such letters and a third addressed to the Prime Minister:***

To: Mr. P. Lloyd MP, House of Commons, London.

I am enclosing an article from ***Spaceflight***, written by Mr. Roy Gibson, which makes some very interesting points. I would be interested to learn what is thought of them in the Department of Trade and Industry.

Whilst the Government is correct to question the expenditure of public money, and seek to spend that money efficiently, I still believe that it has gone too far in restricting public investment in space activities. If ESA cannot provide economic vehicles for investment, there is then scope for a national programme. Once our level of spending falls too far, we might as well give up all together.

It can be argued that there is no need for public investment in areas such as satellite communications, where there are already several commercial developments under way. However, European abilities to compete with American manufacturers of both satellites and Earth stations is extremely limited because of the market conditions in Europe. The regulatory stranglehold of the PTTs in the field of telecommunications has restricted the growth of a satellite communications industry and the much greater size of the market in America allows those firms a much better competitive edge.

In other areas of space activity, the argument for public investment is much stronger. Commercial activity and investment will not be possible on a meaningful scale in, for example, Earth resources and microgravity applications until the technologies and markets have been further developed. Until that time, public investment is required to ensure that British and European abilities mature to the same level as our competitors.

I hope that Mr. Clarke will take the opportunity to reply to these and all the other points that have been made on this subject in the columns of ***Spaceflight***, which is the UK journal in this area. In particular, a response to Mr. Gibson's article would be very welcome.

PETER H. MILNE
Fareham, Hants

To: The Rt. Hon. Sir Geoffrey Howe, QC MP, House of Commons, London.

The Channel tunnel is soon to swallow vast amounts of money for the dubious privilege of physically uniting us with mainland Europe. The extraordinary enthusiasm of the Government for this unpopular project contrasts strangely with its disinterest in, or downright hostility to, the British space programme.

The excuse of shortage of public funds, and the attempt to foist the whole burden of cost onto private industry, just will not do. Few people believe that the Channel tunnel will be financed wholly by the private sector, and more beneficial projects such as space exploration must rely initially on moral and material support from governments in advance of participation by industry. Two of the successful countries in the space field, India and China, are much poorer, financially, than the UK.

Our space programme, suitably encouraged and judiciously funded, could have created more jobs country-wide, been a source of pride and inspiration to the British people (particularly the young), and made a significant contribution to the fight against the global problems which threaten, long-term, to engulf us all.

I would like to ask the Government through you, as my MP, the following questions:

1. Why set up the British National Space Centre in 1985, thereby raising the hopes of so many of us who falsely assumed that we were, at last, entering an era of enlightened leadership?
2. Why encourage an administrator of the calibre of Roy Gibson to become Director-General of the BNSC only to deny him the necessary funding two years later, thus forcing him to resign?
3. Why sack Sir Geoffery Pattie, the only member of the Government to have shown any real enthusiasm for space projects?
4. Why replace him with Kenneth Clarke, whose idea of encouraging the outside world to take us seriously would seem to be to insult the European Space Agency by calling it "a hugely expensive club", thus revealing a profound ignorance of its past achievements (under Roy Gibson), and its future potential, in which we could have played a decisive part?

Mr. Clarke's outburst was all the more regrettable for being made just before the prestigious International Astronautical Federation Congress, held in this country for the first time in 28 years. Mr. Clarke then compounded his rudeness by not bothering to attend the Congress. This snub from the government of the host country was received by the delegates with dismay and disgust. How sad that *this* government, by its negative and shilly-shally attitude, should encourage the growing view that Britian is fast becoming a third-rate country, peopled by hooligans, lay-abouts and fast-buck operators. No wonder many of our fine scientists and administrators feel frustrated and betrayed.

I am enclosing a copy of an article by Roy Gibson from the February issue of ***Spaceflight***, the magazine of the British Interplanetary Society. In it, Mr. Gibson explains, so much better than I, what this country could have achieved in Europe, given the right governmental support.

I will end this letter with a quote from the book "The Promise of Space" by Arthur C. Clarke:

> "... there is no way back into the past; the choice, as Wells once said, is the universe – or nothing. Though men and civilisations may yearn for rest, for the dream of the lotus-eaters, that is a desire that merges imperceptibly into death. The challenge of the great spaces between the worlds is a stupendous one; but if we fail to meet it, the story of our race will be drawing to its close. Humanity will have turned its back upon the still untrodden heights and will be descending the long slope that stretches, across a thousand million years of time, down to the shores of the primeval sea."

For "humanity" read "politics". If unimaginative politicians persist in regarding short-term gains as more important than long-term solutions to our planetary problems, then we shall all be descending Arthur's slippery slope far quicker than we crawled up it.

MRS. M.E. MASON
Redhill, Surrey, UK

To: The Rt. Hon. Mrs. Margaret H. Thatcher, Prime Minister, 10 Downing Street, London.

I recall with pleasure the privilege I had in meeting you personally in Sussex shortly before the last General Election. I am writing to you directly on a matter that is causing me and

a number of important people great concern for the future of our country. I refer, of course, to the pitiful lack of support and involvement by Government in science and technology.

The future of any developed country will without question be largely dependent upon the quality and success of that country's science and technology, particularly in the new environment of space technology. At present, the best of our industries are highly regarded for their first class involvement in the design and production of satellites and other space projects, which do of course lead to many other areas of technological developments. However if we continue on our present financial strategy in these areas, then undoubtedly our future involvement in producing satellites and other technical contributions will diminish by default.

Although I appreciate there are many other important demands upon the Exchequer, the amount of finance required to maintain our technical position in the developed world is small in comparison and represents the seed corn of our country's future technological harvest. We also have the incredible situation where Britain provides money and aid for India and yet this 'poor' country has its own costly space industry and now plans its own space shuttle – a lesson for the wise to surely note!

I would hate to see posterity record that your Government's achievements are forever marred by historians pinpointing the crucial decline of Britain as a first class nation by our failure to reasonably invest some of our hard pressed resources in support of our outstanding scientists and technical expertise that is second to none.

S.A. COXHEAD
Eastbourne, UK

Tapping New Resources for Space Cash

Sir, I write in response to the letter by Mr. Simpson published in the February issue of ***Spaceflight***, (p.70). Important though investment in space is, it cannot, surely, be considered so much more important than human life that development aid for the poorer parts of the world should be diverted to it. Viewed from any sort of moral position this suggestion is perverse in the extreme. It is all the more difficult to understand when one considers the (regrettably) small level of overseas development aid provided by the UK government, far short of the 0.7 per cent of GNP recommended by the United Nations.

Mr Simpson is right, of course, that the money for space has to come from somewhere, but we should be looking to take it from a much richer, and less useful, source than development aid. The primary candidate is the military budget. Not only is this a more acceptable alternative from a moral point of view (weapons are used to kill people, development aid to improve the quality of life) it also makes political and economic sense.

The tail end of last year saw the agreement between East and West to remove intermediate range nuclear missiles from Europe, and there is now real hope of a major reduction in strategic arsenals. For those of us interested in the future of humanity (in space or on Earth) these political moves can only be seen as good news. The only stumbling block that stands to prevent the expansion of humanity into space would be a major war between East and West, and the further that danger recedes, the more likely are our dreams of space exploration and colonisation to become reality. It is in this political climate that we can make the connection between disarmament and investment in space.

Probably one of the major factors inhibiting the disarmament process is the high level of investment in high-tech industries, most of whose efforts are directed at the military sector. From an economic point of view, the West, in particular, cannot afford to run down these industries. It follows that, in order for disarmament to become politically acceptable, alternative business for the industry must be found. Allaby and Lovelock [1] have pointed out that investment in space provides an obvious alternative. Many of the industries that at present produce sophisticated equipment for the military would be just as happy (perhaps happier) developing hardware for space applications.

Thus an increased level of government investment in space can be seen as complementary to the disarmament process. The world spends more than $1000 billion (8 per cent of its GDP) on weapons every year, compared to about $20 billion (0.2 per cent of GDP) on civilian space applications. There are vast resources here that are potentially available for both space investment and world economic development.

IAN CRAWFORD
London, England

References

1. Allaby, M. & Lovelock, J. *"The Greening of Mars"*, Andre Deutsch Ltd., London, 1984, p.135.
2. Brandt, W. *"World Armaments and World Hunger"*, Victor Gollancz Ltd., London, 1986, p.43.

Space Age or Stone Age?

Sir, Let's hope and pray that the UK government is not as short-sighted and ignorant as it leads us to believe. We might as well go back to living in the Stone Age if the government ignores the chance to be on the leading edge of technical advancement in the years to come. Has anyone told the Prime Minister, Margaret Thatcher, that we are supposed to be in the Space Age?

DAVID RABY
Aviemore, Scotland

British Aerospace Capsule

Sir, In reflecting on the UK's funding controversy within ESA, it seems very unfortunate that the British Aerospace capsule concept (***Spaceflight***, January 1988, p.9) was not considered as an alternative to the Hermes spaceplane. Such a spacecraft could be developed sooner and less expensively than Hermes.

Hermes' plans call for only two vehicles and two to three flights per year. Does such a low flight rate economically justify the development of a reusable spaceplane? The British Aerospace capsule could launch larger crews and the capacity to serve as a rescue craft would offer some potential for financial co-operation with the US, something the three passenger Hermes design does not.

If all of ESA's major programme options are followed up and even one experiences the the sort of cost overruns that such pioneering efforts often do, then European budget directors could face some hard choices to be made. Under such circumstances, Hermes would likely be the most vulnerable. Stretching out the programme would put off Hermes' first flight into the 21st Century and cancellation would set back the goal of independent European manned access to space for many years more. The spaceplane enjoys a certain institutional inertia, provided by CNES, that the capsule concept does not, but this should not blind ESA to other alternatives.

GARY SMITH
Ontario, Canada

New Member

Sir, I have only been a member of the BIS for five weeks now, but I have found your magazine ***Spaceflight*** so enjoyable and interesting. I did not realise the astronautics could cover such a wide field.

A. HUNTER
Preston, Lancashire

CORRESPONDENCE

Media Attention

Sir, I share the surprise of Paul Lister (**Spaceflight**, January 1988, p.29). Space has rarely been out of the news over the last couple of years or so, yet I have neither seen nor heard any mention of the BIS in the general media.

There were many reports of the IAF Congress in Brighton, but I cannot recall seeing any mention in the general press of the superb Space '87 Exhibition or of the fact that the whole thing was organised by the BIS. Even the specialised press seems to have ignored the Society's role.

RAY WARD
London, UK

Ed. *The following tribute was paid to the Society as part of a report on the IAF Congress and Space '87 by* **Space World** *(December 1987):*

The British Interplanetary Society (BIS) organised the meeting. Formed in 1933, the BIS was one of the founding members of the IAF in 1951 and in 1987 BIS members and employees did a commendable job of running the 38th IAF Congress.

Appreciation and Support

Sir, Once again I have to make a late renewal of my subscription. It seems that things are becoming harder every year, though I do not complain about the subscription rates. As a matter of fact only the extraordinary work of your dedicated people explains why they are so low.

I received my first **Spaceflight** 17 years ago and became a member 15 years ago. I do not intend to stop being one. It would be unfair, especially because membership is increasingly rewarding each year.

So I hope everything continues to turn out fine for the Society and that the excellent work it is doing expands. I will go on supporting it as long as I can.

F.E. NOGAL
Lisbon, Portugal

Soviet Astronautics

Sir, Congratulations to everyone who contributed to this year's *Soviet Astronautics* ***JBIS***. It was every bit as good as the classic 1983 issue.

G. J. COX
Surrey, UK

Ed. *Copies of this edition of the Journal of the British Interplanetary Society, published in March, are still available, price £10.00 (US$18.00) to non-members, £3.00 (US$6.00) to members, post included, from the Society at 27/29 South Lambeth Road, London, SW8 1SZ, England.*

Apollo – Saturn V Launch Abort Modes

Further replies to the letter of Mr. Gordon Davie (January 1988, p.27) about CAPCOM calls during the early phase of a Saturn V launch have been received in addition to those published in the February issue (p.73). The editor gratefully acknowledges receipt of the detailed information provided by Gregg Linebuagh and John Fongheiser.

Sir, After reviewing several Apollo/Saturn 5 launches, from both audio/video and document sources in my collection, the launch sequence procedes as follows:

In the first seconds of launch, the vehicle executes a "yaw manoeuvre" to increase the lateral distance between the vehicle and launch tower. The first communication from the crew usually was confirmation of the "roll programme" that alined the Saturn 5's body axis with the desired flight azimuth. The next call from the crew was start of the "pitch programme" that provided a trajectory that satisfied vehicle performance, heating and load requirements.

All of the above events occurred under the Mode One abort regime. A Mode One abort could occur in the portion of the launch within the atmosphere (0 to 3 minutes). This region of flight was protected with an automatic abort and emergency detection capability and the launch escape system (LES) rocket above the command module (CM).

A call from CAPCOM would tell the crew they were in 'Mode One Bravo". Bravo is basic pilot talk for "B". I assume that Mode One "Alpha" or Mode One A is an abort in the close proximity of the launch tower. However, I could find no reference of this in documents or communications. Mode One Bravo occurs after the tower has been cleared and up to the point of maximum dynamic pressure (Max Q) on the Saturn. The next call was "Mode One Charlie" meaning Mode One C, telling the crew that they were in the last part of a Mode One abort, after Max Q.

After the Saturn's 1st stage (S-1C) shutdown at T+ 2 min and 40 seconds the second stage (S-II) engines started. Then the S-II aft interstage was jettisoned and six seconds later the LES was jettisoned. At LES jettison, the Apollo/Saturn entered the Mode Two abort regime. CAPCOM then called "your Mode Two" after the crew called "skirt (aft interstage) sep" and "tower (LES) jet" (jettison).

A Mode Two abort consisted of separating the command/service modules (CSM) from the launch vehicle, then seperation of the command module (CM) from the service module (SM) and the CM parachuting into the Atlantic Ocean between 440 and 3200 nautical miles downrange. Mode Two lasted from approximately T+ 3 to T+ 9 minutes.

During the Mode Two abort regime, two calls from CAPCOM occurred. The first was at T+ 4 minutes, telling the crew that the "trajectory and guidance had converged", or had met the desired parameters and that "the CMC is go". CMC stands for Command Module Computer. On some missions the crew gave CAPCOM the above calls!

Also during Mode Two a call "S-IVB to COI capability" would occur when the flight was far enough along to allow the Saturn's third stage (S-IVB) to get the CSM into orbit if the S-II shut down prematurely. COI stands for circular orbit insertion. At S-II stage shutdown and S-IVB engine ingition, the crew entered Mode Four. A Mode Four abort occurred if the S-IVB shut down too soon just prior to orbit insertion (T+ 9 to 12 minutes). The crew would seperate the CSM and use the Service Propulsion System (SPS) of the SM to continue to a safe Earth orbit insertion.

A mode Three abort was a secondary technique used only if it was undesirable to continue to orbit. The crew would separate from the launch vehicle and using the SPS retrograde to achieve a landing some 3000 to 3400 nautical miles downrange.

GREGG LINEBUAGH
Mitchellville, USA

Sir, To assure clarity in the mode callouts from the Mission Control Center, words were substituted for the letters in the mode names. So, Mode IA became "One Alpha", Mode IB became "One Bravo" and Mode IC became "One Charlie".

Your readers greatly appreciate this forum for making comments and getting answers – a unique trait of your magazine.

JOHN FONGHEISER
Space Consultant
California, USA

CORRESPONDENCE

Supernova 1987A and CETI Activities

Sir, In the past few years several people have suggested the use of supernova as beacons for attracting the attention of would-be CETI searchers. Upon sighting an outburst the searchers could then examine the vicinity of the supernova for a considerable period, believing that other civilisations would transmit to likely solar-type candidates.

The very best opportunity for testing this logic has now occurred in the shape of Supernova 1987A. This has "beaconed" the large Magellanic Cloud – a cluster large enough to embrace several tens of thousands of solar type stars.

The LMC is sufficiently far away (160,000 light years) to provide any potential CETI transmitters at the LMC with a superb target to aim at – the Milky Way.

Allowing that the "nearest" civilisations in the LMC would lie between 30 and 300 light years from the supernova, would-be CETI listeners may have to wait until 2017 or later for transmissions.

Nevertheless, 1987A must be looked on as the outstanding beacon event for CETI search area definition.

A.T. LAWTON
Goring, Sussex, UK

Best Large Telescope

Sir, I refer to the report on the progress of the new Keck telescope in 'Space at JPL' (***Spaceflight***, February 1988, p.64).

I feel we should perhaps question the author over the statement that "Mount Palomar remains the world's premier large telescope". The author, in his previous sentence agrees that the largest is the Soviet six metre so by what criteria is Palomar the premier?

If the claim is based on accuracy or precision, then does not the Anglo-Australian (150 in) or the William Herschel (4.2 m) better the Palomar (200 in)? From the results obtained since first light in May 1987, especially those taken during November and December 1987 (maybe after the article was written), I believe the new William Herschel 4.2 m must now be considered 'best-in-the-world'. Perhaps the RGO or La Palma would confirm with results or maybe an article for inclusion in a future edition of ***Spaceflight***.

TIM COLLINS
Derby, England

Information Available

Sir, It was very pleasing for me to see my letter in ***Spaceflight*** (August 1987, p.298). Thank you very much.

I was astonished by the discussion in ***Spaceflight*** (March 1987 and April 1987 issues) about launch times of the Soyuz 4 and 5 spacecraft. Soviet sources quoted the correct launch times of these vehicles many years ago.

For example, in the book 'Overcoming Weightlessness' (Voyenizdat Publ, Moscow 1976, p.56) Yevgeni Khrunov gave the Soyuz 4 launch time as 10.30 MT. In his book 'The Reliable Orbit' (DOSAAF Publ, Moscow, 1978, p.51) Anatoli Filipchenko said: "On January 14 at 10 hours 30 minutes Shatalov was launched and on January 15 at 10 hours 5 minutes Volynov Yeliseyev and Khrunov were launched".

Other Soviet sources have quoted data of Soviet space flights, including Soyuz 8 and Soyuz 14. So why all the calculations and discussions?

I think that ignorance or poor knowledge of the Russian language prevents some Western authors from undertaking a correct analysis of Soviet space programmes.

VADIM Y. MOLCHANAOV
Tula, USSR

Three-stage Soviet Cyclone Launcher

Sir, The Soviet Union recently displayed for the first time a model of its three-stage Cyclone space launcher [1]. The Cyclone, although generally considered a Type F launcher, appears somewhat different from the Soviet SS-9 missile, which has long been considered the basis of the F class launchers. However, on the basis of the model of the Cyclone, the following reconstruction of both Type F launchers is now possible:

Soviet Designation	Cosmos	Cyclone
LoC Designation	F-1	F-2
DoD Designation	SL-11	SL-14
First stage thrust (in tons)	~300	~300 (At Sea Level?)
Number of Engines	6?	6?
Specific Impulse	NA	NA
Second Stage Thrust (in tons)	90	60 (in vacuum)
Specific Impulse (in seconds)	293	~330
Third Stage Thrust	NA	NA

The second stage of the Cyclone is visibly different to the second stage of the SS-9, due to the four vernier engines which are mounted on the exterior of the Cyclone second stage airframe. A possible explanation for the unique external mountings may be that the Cyclone second stage engine design is shared with the Proton orbital stage. Although the Proton's verniers are located within its four metre-diameter airframe, the Cyclone airframe has a reduced diameter (3 m), resulting in the external mounts.

Glushko's account of the RD-219 engine that reportedly powers the F-1's second stage implies a dry mass of about 4000 kg for the second stage [2]. Photographs of the SS-9 second stage (which is assumed to be the F-1 second stage) show the stage to have a length of about eight metres, and a diameter of about three metres. The Cyclone model shows its second stage to have dimensions similar to these. I have failed to find a report of a rocket stage in orbit with these characteristics. Thus, it would appear that there have been no two stage variants of the Type F.

It is probable that the Type F first stage engine shares much, if not all, of its design with the Proton upper stage engine. Both engines were developed in the early 1960's, probably in the Kosberg Design Bureau (Glushko has stated that the Proton upper stage engines were designed by Kosberg [3]. It is still uncertain which bureau created the Type F first stage engine, but Glushko has not claimed credit for its design, implying the Kosberg Bureau as the designer).

The third stage of the Type F launcher is still a mystery. The Cyclone orbital stage is reported in the RAE tables to be similar in mass and size to the Type C upper stage. However, a recent photograph of the F-2 upper stage [4] shows it to be somewhat different in appearance from the Type C orbital stage.

DAVID ANDERMAN
California, USA

References

1 "Soviets Stress Cooperative Ventures at Space Forum", *Aviation Week & Space Techology*, October 12, 1987, p.26.
2. "Kosmonavtika Ensiklopedia", V.P Glushko, editor, Soviet Encyclopedia, Moscow, 1986, p 330
3. V P Glushko, op cit, p 171
4. *Spaceflight*, December 1986, p.417

Soviet Back-up Crews

Sir, In the February 1988 issue of ***Spaceflight*** (p.72) Anne van den Berg suggests that cosmonaut Alexander Viktorenko must have been Soyuz 13 back-up commander, with Vitaly Sevastyanov being the back-up flight-engineer. Valery Bykovsky has been suggested instead of Senastyanov, and she asked if he fits.

In the Soviet picture book '*To the Stars*', 1986, p.45, there is a photograph to support Bykovsky's inclusion in the crew. The photograph shows, from right to left, Shatalov,

Bykovsky, Viktorenko, two Soviet officials and another possible cosmonaut. The caption next to the photo is: 'The next spaceship crew is ready for control checks. Vladimir Shatalov, in charge of their training, briefs them on their programme'.

Unfortunately, the photograph is not dated, but the Soyuz 13 back-up crew seems to fit the bill. An alternative is a scrapped Salyut 2 assignment. One puzzling aspect of the photograph is the unknown cosmonaut at the left of the picture. He looks very much like Pavel Belyayev, who died on January 10, 1970, while Shatalov was only appointed Director of Cosmonaut Training in October 1971.

An additional point: Musa Mananov, according to 'Trud', December 22, 1987 was born in Baku. Unless I am mistaken, this is in the central Soviet Republic of Azerbaijan and this makes him unique from other cosmonauts, who traditionally, have come from Russia.

NEIL DA COSTA
London, England

Soyuz TM-4 Crew

Sir, In a background article on the Soyuz TM-4 crew members, Pravda's space correspondent A. Tarasov noted [1] that Titov had been training as prime crew commander for last year's Soyuz TM-2 to Mir and that Yuri Romanenko and Alexander Laveikin were originally the back-up crew. It is known from other reports that Titov's flight engineer was Alexander Serebrov. During final launch preparations at Baikonur it was decided to swap the main and stand-by crews, *Pravda* disclosed. No reason was given for the late crew change, only that it was "not through a fault of the crews".

Romanenko and Laveikin were officially announced to the world as flight crew on January 28, 1987, which means the switch must have taken place some time between then and the crews' arrival at Baikonur on January 23. It was another major disappointment for Titov, who has already been on two jinxed spaceshots to Salyut 7 in 1983. However, he was given a new chance and in April 1987 started training with Musa Manarov and Anatoli Levchenko for Soyuz TM-4.

Manarov, the first non-Slavic Soviet cosmonaut (he hails from the Transcaucasian republic of Azerbijan), had been a shift Flight Director for Mir at Mission Control until his TM-4 assignment and was apparently called upon to replace Serebrov in the recycled Titov crew. He is now on board Mir with Titov for a planned year-long flight. Levchenko is one of the civilian test pilots being groomed for the Soviet space shuttle programme and was on a one week warm up flight to acquaint himself with zero gravity in preparation for future shuttle assignments. Cosmonaut Igor Volk, another civilian test pilot selected for cosmonaut training in 1978, similarly rode the passenger seat on Soyuz T-12 in 1984 and went on to become chief pilot for the shuttle approach and landing tests now underway at Baikonur [2].

BART HENDRICKX
Kapellen, Belgium

REFERENCES
1 "Pravda", December 22, 1987, p 3
2 "Aviation Week and Space Technology", October 12, 1987, p 22

Arrests 'Limited' Rocket Development

Sir, New information about the activities of Soviet Chief Designer Sergei Korolev have been disclosed by "Ogonyok" magazine. Writing that the period 1938-1945 of Korolev's life had been "usually ignored" or had "half-truths" written about it, the magazine gives details of the Chief Designer's fate during those years.

On June 27, 1938 Korolev was arrested by the NKVD (the predecessor of the current KGB) on charges of being a member of an anti-Soviet organisation. He was also accused of sabotage of new technology and was sentenced by the Higher Collegium of the Supreme Court in the autumn of that year to ten years' jail.

The arrest had taken place after the internment of Valentin Glushko, another major Soviet designer, when Korolev said in public that he did not believe that his colleague could be a public enemy. Several days later Korolev himself was arrested.

Of the investigation into his alleged crimes Korolev later wrote: "There was no investigation in the proper sense of the word. I was bluntly accused of sabotaging research in new technology. I could not imagine a more absurd and incredible charge...".

Korolev's sentence included a spell as an earth digger on the Kolyma River where he was brutally treated to the point that he was left with a scar on his head and he lost half his teeth from scurvy.

In 1939 the original sentence was overturned by an NKVD special meeting at which Korolev was not present, and a new sentence of eight years in a corrective labour camp was imposed on him.

Korolev was released in 1944. He began work on rocketry again for the war effort and was cleared of his criminal record. However, it was only in 1957 that he was rehabilitated completely. Korolev was later to write only small references to his "nightmarish time".

Korolev was said never to have doubted the "honesty and sense of justice" of Stalin and wrote from Kolyma to the leader. It was only after the revelations made by Khruschev in 1956, in a closed session of the Supreme Soviet Party Congress, that Korolev saw the true picture.

The magazine claims that the German engineer Wehrner von Braun was "jealous" of Korolev's achievements in later years. One of Korolev's colleagues, Georgi Tyulin later wrote that if there had been no arrests then Soviet rocketry would have achieved a very high technical level in the late 1930's. Instead their developments stopped at powder rockets, and development of liquid rockets only began in earnest after Stalin's interest in the V rockets was stimulated.

N. KIDGER
Leeds, England

Artificial Gravity

Sir, Recently there has been discussion of the effects of prolonged weightlessness on humans following Yuri Romanenko's return from Mir. Even the media went into the details of calcium loss from bones, muscle deterioration and changes in circulation due to weightlessness.

With a few exceptions, however, the obvious solution of using centrifugal force to create artificial "gravity" has virtually been ignored. By simply spinning the ship, a force directed away from the axis of spin is produced. The idea was suggested by Konstantin Tsiolkovsky in 1903.

A ship for a mission to Mars would have its crew area joined to the engines and propellent tanks by a tether long enough to simulate normal Earth gravity.

Because the level of gravity is under the crew's control it could be reduced during the flight to that on Mars and avoid the need for the crew to adjust their reflexes accordingly.

Spinning the ship avoids all the medical problems associated with weightlessness and is also applicable to small space stations such as NASA's present plans for the 1990's.

Despite the USSR's research into long periods without gravity which seems to indicate they do not intend to use simulated gravity, this still provides a complete solution to the ill effects experienced, and should therefore receive more attention.

A. McNAB
Glasgow, Scotland

EUROPEAN RENDEZVOUS

ESA Targets Future Commercial Areas

by Norman Longdon

In two previous articles (*Spaceflight*, January 1988, p.34 and March 1988, p.125) we looked at the policy approved by the ESA member states to give Europe a series of programmes into the 21st century, and discussed the space science and Earth observation programmes. Now we look at the microgravity and telecommunications programmes – two aspects of space with proven or potential commercial applications.

Microgravity

The term 'microgravity' is used to describe the physical environment in an orbiting spacecraft. The most obvious feature of this environment is its extremely low gravity, which is not obtainable on Earth for long periods of time. This environment offers new possibilities in basic material science, fluid science and life sciences, due to the practical absence of natural buoyancy, of sedimentation, and of thermal convection and hydrostatic pressure in a fluid.

The interested 'layman' (or should it be lay-person?) may not have been aware of the effects of microgravity beyond seeing that the men who walked on the Moon could 'bounce' along, and carry apparently greater weights of materials etc. However, the fact that solid particles do not fall to the 'bottom' of a liquid sedimentation, and other new effects can be used in many different ways.

Despite the limited flight opportunities so far, the first results obtained have shown that very interesting phenomena can be observed and explored. An entirely new research field is now opening up, one which promises to expand rapidly as the facilities on the Eureca platform and the international space station become available.

Results of four years work in the field are summarised in Table 1.

In working out the long term programme for the period 1988 to 2000, the assumption has been made that, from 1997 onwards, the large majority of microgravity activities will be performed on the space station/Columbus orbitial facilities, i.e. the Pressurised Modules, the Co-orbiting Platform, and, to a much smaller extent, the Polar Platform of Columbus. The Microgravity Long-Term Programme Proposal is therefore subdivided into two distinct periods:

1. The Pre-Columbus Period (mid-1989 to 1997).
2. The Columbus Utilisation Period (1998 to 2000).

The Pre-Columbus Period

Due to the lack of flight opportunities following the US space shuttle accident, the first part of the phase will last about three years longer (mid-1992) than originally planned. The intention is to increase the mini-mission activity, covering a Mini-Botany Facility, and financing the utilisation of shuttle-independent retrievable space systems.

This Pre-Columbus phase covers hardware development of the Microgravity experimental facilities for all Columbus elements (APM, MTFF, PPF and Eureca).

The development (Phase C/D) of microgravity experimental hardware for all Columbus elements should be completed by 1997.

The assumptions regarding the experimental hardware development for the different Columbus elements are:

Eureca

Although Eureca is not a formal Columbus 'element' it will be of considerable value during the early stages. It is assumed that during the development of the manned Pressurised Modules and Man-Tended Free Flyers, there is still a need to fly material-science experiments on free-flying platforms. Many of those experiments involve toxic materials, which for safety reasons might not be accepted on manned systems. It is therefore assumed that two reflights of Eureca in 1993/94 and 1995/96 (including the refurbishment of its core payload elements) will be covered by this phase.

Table 1. Results of recent microgravity work.

Research Field	Results obtained during first phase of Microgravity Activities (1982-1985)
Crystal Growth	• improved chemical homogeneity, better structural properties and more uniform distribution of dopants. • Much larger protein crystals, enough to perform structural analysis.
Metallurgy/Composite Materials	• Much more precise determination of thermo-physical properties. • New phase separation mechanisms exist for immiscible materials.
Fluid Science	• Very interesting results show that present theoretical models are inadequate.
Electrophoresis	• Very high processing rates. Moderate increase in purity level.
Cell and Development Biology	• Strong evidence that gravity affects biological organisms. • Pronounced changes in cell differentation and cell prolifertion.
Human Physiology	• Better understanding of the functioning of vestibular and cardiovascular systems.

Preparing for Columbus

The general objective of the ESA Microgravity Programme is to prepare the groundwork for future microgravity operations in space. The first phase will, therefore, promote fundamental research in the material-and life-sciences and establish a database from which future users from research institutes and industry can draw the necessary knowledge.

The material-and life-sciences community is likely to be a major user of the future low-Earth orbit infrastructure. Life-sciences and fluid-physics research will be the main users of the manned laboratories, whereas crystal growth and processing of metals will be mainly performed on unmanned platforms.

Attached Pressurised Module (APM)

It is assumed the 45 per cent of the 40 single racks (or 20 double racks) that can be accommodated in the Pressurised Module will be developed by ESA and that the remaining 55 per cent will be developed by national agencies of member states , by non-European space agencies (e.g. NASA) or by commercial users.

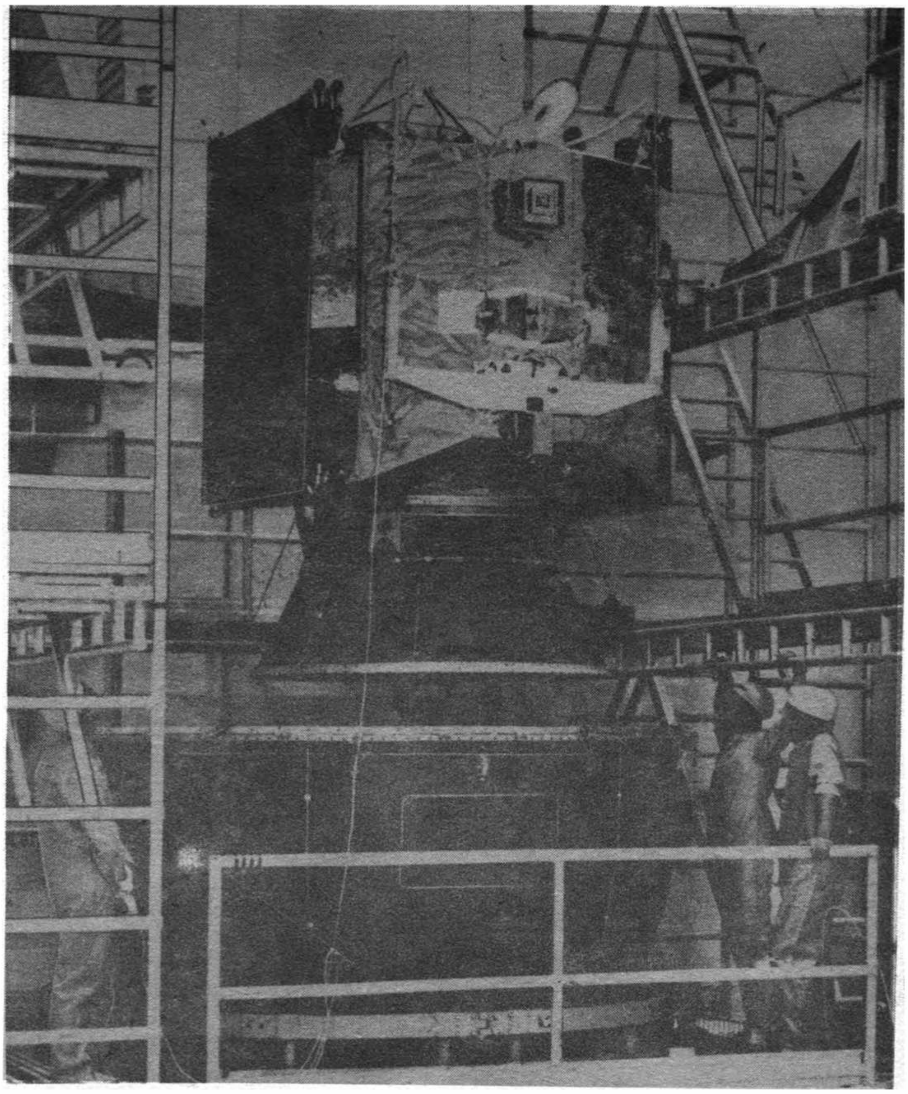
Man-Tended-Free Flyer (MTFF)

The MTFF will mainly be used for long-term material-science investigations (e.g. crystal growth) and automatic processing of biological materials, both requiring long periods of undisturbed microgravity conditions.

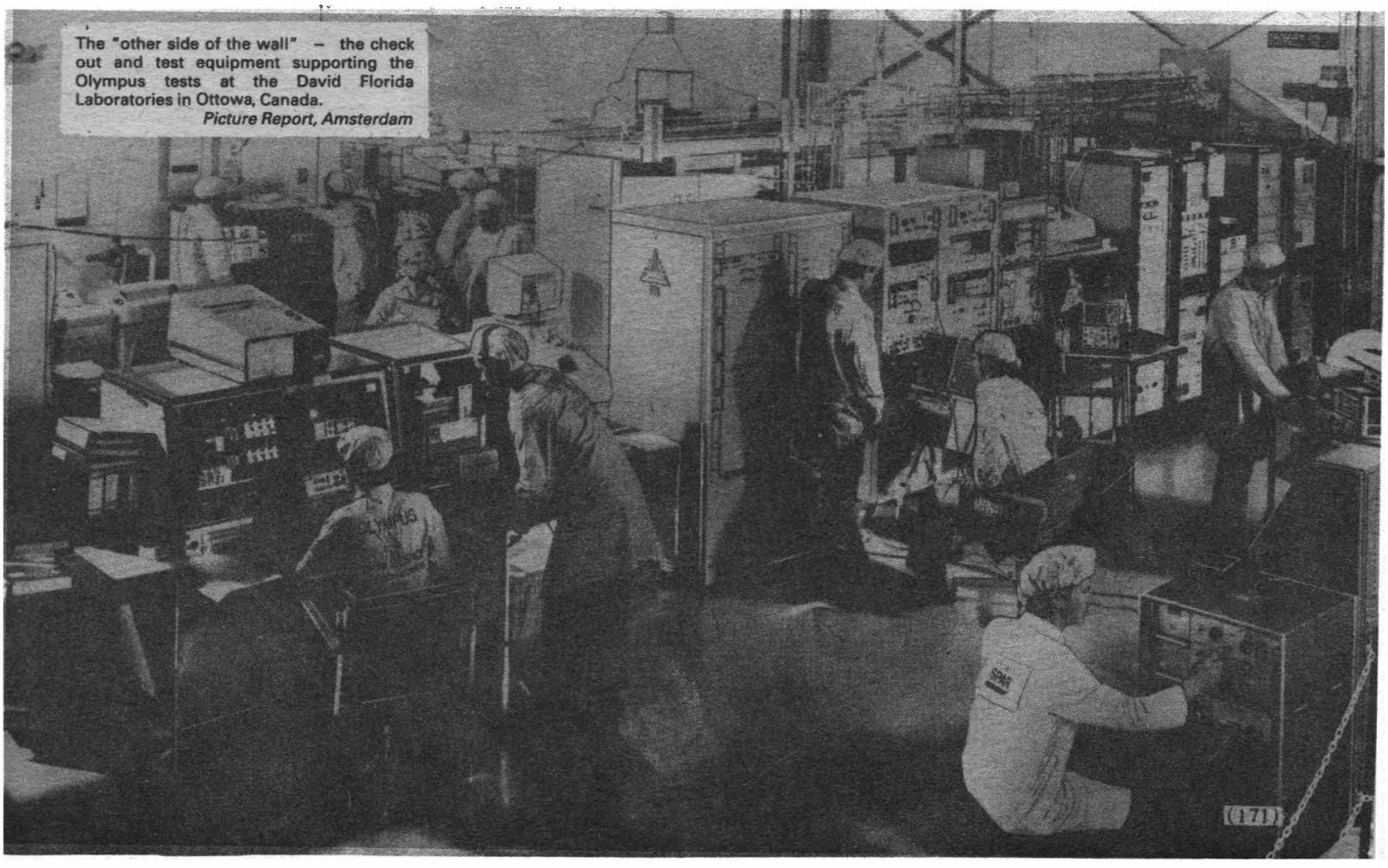
Based on present MTFF design requirements, it is assumed that 10 experiment-dedicated double racks (DRs) or 20 single racks can be accommodated and that the equivalent of 10 further DRs will be available for MTFF subsystem and experiment stowage. It is further assumed that five (or 50 per cent) of the experimental DRs will be provided by the Agency and the other 50 per cent by member states or commercial users.

Polar Platform (PPF)

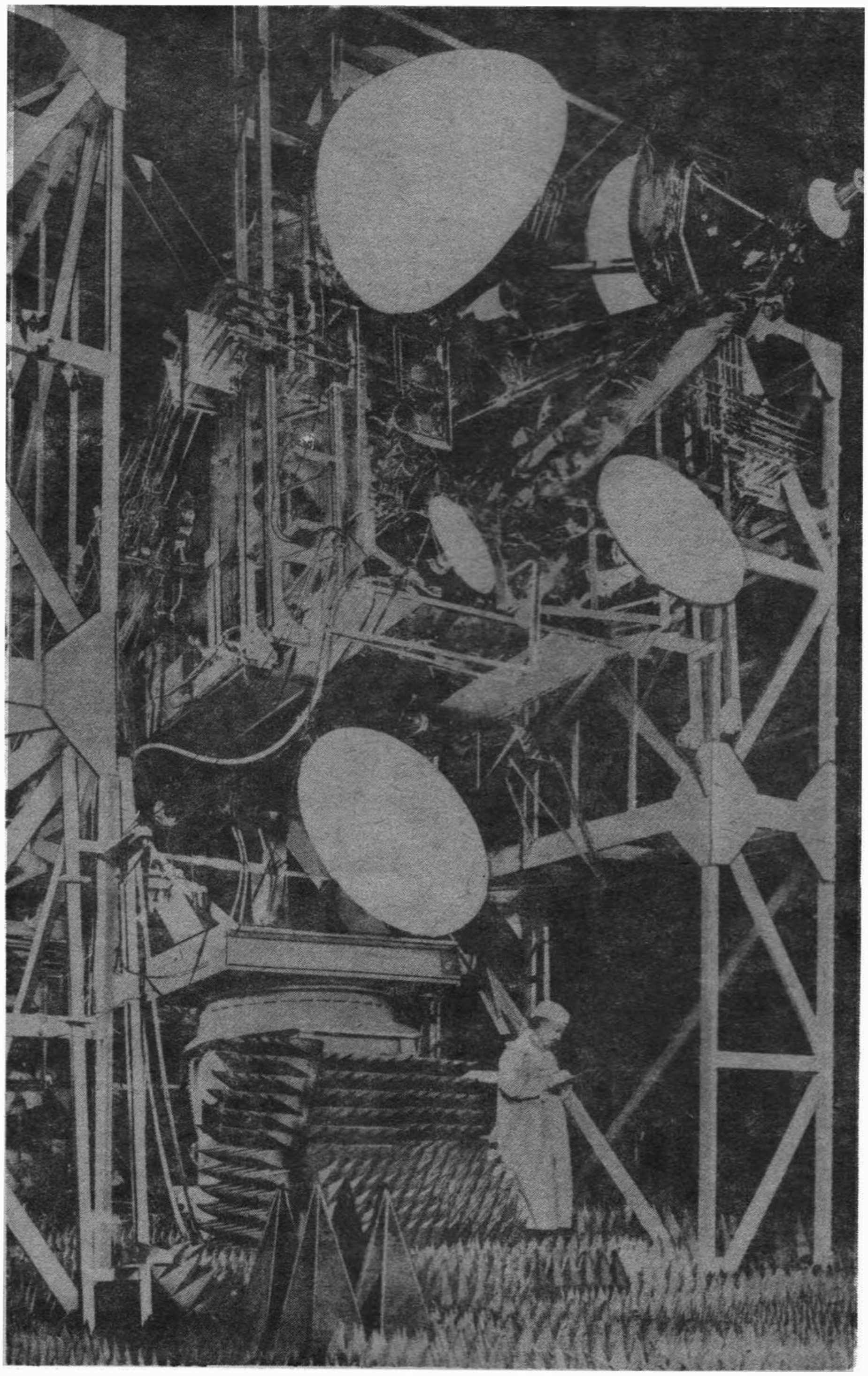
Life scientists interested in radiation biology and exobiology require flight opportunities on Polar Platforms with Sun-synchronous orbits of some 800 km altitude, in order to study the biological and biomedical implication of the ionising radiation environment of space. It is proposed to develop a second-generation 'Exobiology and Radiation Assembly' (ERA – the core payload facility of the Eureca-1 mission) for flight on the Polar Platform.



ECS-4 being lowered into the Sylda casing which protected it during its dual launch. *ESTEC*



The "other side of the wall" – the check out and test equipment supporting the Olympus tests at the David Florida Laboratories in Ottowa, Canada.
Picture Report, Amsterdam



Olympus communications satellite undergoing tests at the David Florida Laboratories in Ottowa, Canada.
Picture Report, Amsterdam

Columbus Utilisation Period

The programme elements of this phase include:

- Supporting technology & support to users.
- Mini-missions.
- Future studies.

There will also be a number of other activities, such as: refurbishment of existing and development of new payload elements; one reflight of Eureca every second year; support to Microgravity-User Support Centres (e.g. MUSC); contribution to Columbus operating costs.

Even when the APM and MTFF are available Eureca co-orbiting platform flights will continue because the use of toxic materials would not be acceptable to the APM and MTFF.

Commercialisation

One could imagine a situation in which major pharmaceutical companies and medical researchers could find answers to some of their remaining problems by investing in microgravity research. The ability to make much larger protein crystals might, for example, give a greater insight into the way enzymes attack proteins, thus opening the way to a better understanding of some major diseases. Certain pure 'mixes' of components are possible which can only be partially achieved in the Earth's gravity. The pharmaceutical companies spend many millions on research, but it may be that the longer time-frame of space research projects does not fit their methods of financing. As with all new features, some re-thinking may be necessary by potential users in their approach if they are to reap rewards.

The same is true of those industries which would benefit from the ability to grow large crystals, or to achieve material alloys which cannot be manufactured on Earth. One is not thinking in terms of mass production but very expensive items which would repay the cost of investment several fold. It is significant that the USSR is already reported to have returned some 500 kg of products to Earth from the Mir space station.

There is an element or risk for those who seek the rewards of commerical enterprise in space, but strangely enough, somewhat less than entrepreneurs take with Earth-bound enterprises, largely because of the meticulous R & D already provided by ESA.

Telecommunications

As almost all families in Western Europe have access to TV sets, the success of ESA's ECS (European Communications Satellite systems) programme is accepted almost to the point of forgetting it exists! Only if some sporting event far from home suddenly fades from the screen does one remember! That service is only the tip of the iceberg as it were.

A strong, coherent and unified ESA effort in space communications is needed to ensure that European industry can maintain and expand its competitive position in this market, and to enable Europe to operate efficiently and independently in other space fields. This effort is needed more than ever taking into account the penetration of US firms and systems into the internal European scene.

A well-directed ESA effort will meet the following programme objectives:

- To develop and ultimately test in orbit advanced space techniques and technology.
- To demonstrate and promote new space communications applications for the expansion of European activities.
- To develop a European in-orbit communications infrastructure (e.g. Data-Relay Satellite), as an integral part of the general in-orbit infrastructure.

The Telecommunications Programme consists of:

- The Payload and Spacecraft Development and Experimentation (PSDE) Programme.
- The Advanced Systems and Technology Programme (ASTP).
- An operational Data-Relay Satellite (DRS) System, as part of the future In-Orbit Infrastructure.

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Spaceflight

The International Magazine of Space and Astronautics

Vol. 30 No. 5 May 1988

Front Cover: A shuttle-deployed tethered satellite system such as the one in this artist's illustration will add a new dimension to experiments in Earth orbit in the 1990's. Ultimately tether applications hold even greater promise – *see p.200*.
Aeritalia

Government Urged to Reveal Space Plan Report

Comment

Eighteen months ago the UK Government received proposals for Britain's Space Plan from its own technical agency, the British National Space Centre (BNSC). The Plan was obviously too constructive (i.e. "too expensive" in Government parlance) and has since been shelved.

Six months ago the Government's response to ESA's future plans was dramatically negative. The Government now repeatedly tries to put on a brave face as it replies to valid criticisms of its actions (or lack of such).

Many letters to *Spaceflight* in our recent Correspondence columns bear witness to the Government's 'game of words', as do letters in the present issue (see p.219).

No properly conceived British Space Plan is in operation. Within itself the Government is dithering as it looks for a way out that will save its already tarnished face, particularly in European eyes.

Pressure needs to be maintained for a change of Government stance and an adequately funded UK space activity. The BIS was privileged to have the opportunity to make representations on its space policy to the BNSC in a private session in June 1986 when the BNSC plan was still being put together. Indeed, if there had been a new Director of BNSC we would have been delighted to continue the dialogue with him. But there isn't one.

BIS influence in promoting a progressive space programme is to be found in the development of international and European cooperation and collaboration over the years. Recently the BIS was among those to submit evidence to the House of Lords Committee on 'UK Space Policy', as reported in the March 1988 issue of *Spaceflight*. BIS space policy was fully presented in that Report, which has now been debated by the House of Lords.

BIS pressure on Central Government has been augumented by that of individual *Spaceflight* readers who have written to their MP's.

The value of such personal representation cannot be over-emphasised. Ministers are kept on their toes and, although their 'game of words' wears irritatingly thin, they continue to give unspecified grounds for undue optimism, as did Lord Young in the Lords' Debate.

We welcome our readers' close interest in these developments (including that of many readers overseas) and extend our thanks to those who have corresponded so frankly and helpfully with us. It is vital now, more than ever to keep the pressure on, to end the Government's 'game of words' and to bring about a genuine action plan for the UK role in space.

A call for the British government to publish the draft space plan drawn up by Roy Gibson during his stint as head of the British National Space Centre (BNSC) was made in the recent House of Lords debate on UK space policy.

The government came in for repeated criticism over its handling of British space interests during the debate on the report of the House of Lords Select Committee on Science and Technology (***Spaceflight***, March 1988, p.124).

Lord Shackleton, chairman of the committee provided a lucid summary of the current situation in opening the lively debate on March 30.

He said: "The first question I wish to ask the Secretary of State is whether this forgotten report could be published even at this stage. We could then know what former advisers thought about space. The whole space community has been left in suspense. And we are still in suspense, wondering for instance when the British National Space Centre will have a new director. British policy in space appears to be rudderless. Indeed, morale is appalling in that part of industry which is interested in space development. It is pretty poor in the British National Space Centre."

Lord Tordoff was also in complete agreement over publication of the report.

"The problem of the investigation was undoubtedly compounded by the uncertainty that has already been referred to as a result of the BNSC report, which never saw the light of day as far as we were concerned," he said.

"We expected it to be published right at the beginning. Indeed it is possible that the committee was set up at that time because that report was expected to be published.

"We were certainly not alone in expecting it to be published. If your Lordships care to look at the evidence of Sir Geoffrey Pattie who, after all, was the Minister who called for the report in the first place, it can be seen that he himself expected it to be published in some form or other.

"In answer to Question 730 from the Lord Chairman the Minister said: 'But as it was no secret the plan was being prepared by a body established with a fair degree of publicity, it was always tacitly understood that the plan would be published in a reasonably unexpurgated form at some stage'.

"In answer to the next question: 'Do you think it should now be published?', the clear answer came from Sir Geoffrey Pattie: 'Yes, I do'. So did we. There is no doubt that this report should be published if we are to have a sensible national debate on the subject.

"If we compare the evidence of Sir Geoffrey Pattie with that of his successor, the present Chancellor of the Duchy of Lancaster [Kenneth Clarke], it shows quite clearly that there was a complete change of direction of government policy between the appointment of Mr. Roy Gibson as Director General of BNSC in 1985 and the statement given by the Prime Minister last summer."

The House of Lords debate went on for some length and cannot be reported in full here. However, the following is a selection of some of the more pertinent remarks and comments which capture the flavour of the debate and cover the main issues.

Lord Shackleton: "When all the major industrial countries of the world and several of the developing countries invest heavily in space, there must be a good reason for it. What do we know that they do not, in deciding not to compete? I cannot believe that we alone are right. In the 21st century space will be a challenging area.

"Unlike the captain of the Star Ship Enterprise who goes boldly into space, the noble Lord [Young] does not appear to be going anywhere into space as captain of the Department of Enterprise. We look to him to override some of the very Earth-bound thinking.

"The optimum level [of expenditure] is believed to be around £200 million per annum, with spending through ESA accounting for about £130 million and the rest going to national and bilateral programmes. This seems to us to be relatively modest when compared with some of the major programmes that are going forward in France, Germany, the United States and Canada.

"Not only is the target relatively modest, but if ever there was a suitable application to the proceeds of privatisation I should have thought that that was it. If we privatise industries, then it makes sense to invest the proceeds in the future of the nation. It is clearly in the national interest that the proceeds should be so invested. The Government will receive several billion pounds over the next few years from their privatisation programme, if we believe what we are told. Therefore, is the financial problem a real constraint? That does not seem to me to be an argument that can be fully sustained."

Lord Orr-Ewing: "There is not much chance of recruiting the right director of the British National Space Centre let alone his deputy – since both the director and his deputy have now gone – if we do not have a plan, new terms of reference and a budget, as well as, I hope, the independence recommended in this report.

"I am puzzled, as many other people must be. I ask myself why, in the last two years, the Government has gone so cold on space. After all, we have just had a very confident Budget. We are told in forecasts from the CBI and everywhere else that the industrial growth of our country is good and will be sustained. Everything seems good and bursting with energy and confidence. Yet the one place where we are not prepared to invest in is space.

"Having reached that inescapable conclusion that we are getting the worst of all worlds, I think the modest suggestion of the committee that expenditure should be

Lord Shackleton.

raised to £200 million is somewhat less than what is required and dictated by the evidence and the conclusions and recommendations of the committee.

"We have a budget of around £120 million. We can apparently give without difficulty a dowry of £800 million to Rover and we can spend £5 billion on the Channel Tunnel. I wholly approve of the expenditure on the Channel Tunnel. However, I believe that it puts the sums which we are discussing into proportion."

Lord Gregson: "In my opinion it is unfortunate indeed that the French have coerced the Agency [ESA] into the folly of manned space flight. I believe that that has deflected ESA from following a potentially exciting and worthwhile course developing space potential of great value to Europe based on good science. Other than rampant nationalism, there is not a case for superimposing the complications of transferring man to and supporting him in space on a significant and worthwhile programme of space science and technology.

"It is well recognised throughout the world that modern tele-operated technology can do almost anything that man can do in space and can do some things a great deal better, at a fraction of the cost and without the human tragedy of a potential failure. There would be some justification if man in space were still a pioneering project. But since the pioneering has now been carried out by the Americans and the Russians it is simply not justified."

Lord Dainton: "It [ESA] has produced a plan for European space research called the Horizon 2000 programme, which has four major priorities that are called cornerstones, and five medium-sized missions.

"Lord Young has told this House that the Government is committed to that programme. Indeed, they accepted the implications for funding the UK subscriptions to ESA up to 1989. However, last November at The Hague the Government did not accept the five per cent per annum funding growth necessary for that programme for the 1990-94 period. Moreover, since approval required unanimity of all the member states this act also blocked the increase that other nations were willing to provide. In fact the Government went further. They insisted that the subscriptions of members newly entered in 1986 – Austria, Norway and Finland – be used not to make the programme go ahead at a slightly higher rate but to abate the subscriptions of existing members and to keep the envelope of expenditure constant.

"Since November, ESA has been probing the effect of the reduced level of resources it now faces. It has stretched the programme to the year 2007. But even so it has concluded – and I do not think that anyone who is knowledgeable in the area can dispute this – that it must eliminate two of the four cornerstones of its programme. These are in X-ray and infra-red astronomy in which fields, the United Kingdom space science community has not only great interests but very great expertise. I fear that flights will become so infrequent that it is doubtful whether our United Kingdom teams can be kept in being. Those who depart from those teams will be eagerly snapped up by our competitors. These are grievous blows to British science.

"What, you may well ask, is the magnitude of the money saved by the Exchequer through this decision? That five per cent per annum on the £21 million per annum that we spend is, in round figures, a mere £1 million extra per year, equivalent roughly to a mere 2p per annum per head of population. Surely in our state of affluence we can afford this small sum?

"Therefore I earnestly request the Government, in their reconsideration of space science, to reverse their earlier decision and thus avoid the kind of damage to British science which I have mentioned and to our relations with other countries which are members of ESA – damage which is out of all proportion to the paltry sums involved, at least as far as space science is concerned."

More of Your LETTERS See page 219

Space Decision Reconsidered

Confusion over British participation in Radarsat, the joint remote sensing venture with Canada, and ESA's Columbus polar platform project reigned supreme in April.

Lord Young, Secretary of State for Trade and Industry, denied that Britain had lost its chance to participate in the £370 million Radarsat programme by failing to make a committment by March 31.

During the House of Lords debate the previous day, Lord Young claimed the deadline was later and the Government would respond "in good time".

Referring to Earth observation, Lord Young said: "We agree that our main effort should go into the ground and user segments so that the space data can be usefully exploited by industry and science".

Roy Gibson, former Director-General of BNSC. The Government has been called upon to publish the space plan he drew up during 1986.

"To ensure proper handling and processing of data we are providing about £4 million a year over the next five years to set up an Earth observation data centre as part of BNSC's National Remote Sensing Complex at Farnborough. In the first instance this will handle data from ERS-1 which should begin in the early 1990's".

"In the space segment, there are a number of projects available. In the period immediately after ERS-1, ESA's first radar all-weather satellite, the Canadian-led Radarsat and ESA's second radar satellite are proposed. Beyond that there is the polar platform with Columbus".

"I am afraid that when we discussed the future scenario with industry at the beginning of this year, there was little consensus emerging among our space companies and potential users on any preferred strategy, nor was there any apparent willingness to make a significant contribution to the heavy costs involved. In those circumstances we could not see why we should join nor what justification there was".

"However, in the past few weeks ESA have been re-assessing with NASA the polar platform requirement and the indications are now that its target configuration will be significantly modified, resulting in a less expensive and perhaps more utilitarian concept".

Lord Young added that ESA would consider how to proceed at a Columbus board meeting on April 18 and the possibility therefore remained open for Britain to look again at its decision not to take part.

"We are urgently re-examining the options and aim to reach decisions as soon as we have had an opportunity to reconsider first of all the latest information from ESA, then the latest information from the UK industry and users," said Lord Young.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events.

Soviet Shuttle Tests — Initial Moves

John Branegan **reviews the implications of some opening moves in respect of the first orbital flight of the Soviet space shuttle.**

Geostationary Relay Satellites

In November 1987 the Soviets successfully launched a Luch geostationary relay satellite which was placed at 85 degrees West, over the west coast of South America. Why this position?

At first sight this location seems to be a 'mistake'. It is exactly the place to put a geosat "if you do not want to talk to the USSR". The equatorial band where a geosat cannot see the USSR is less than 50 degrees wide and this geosat, Cosmos 1897, is right in the middle of this band.

However, it is sensible to ask whether the Russians might after all have a good reason for putting it there, despite its lack of direct relay facility to the USSR, and the diagram below shows what this special reason may be.

This figure is based on the premise that present coverage of Soviet ground communications are positively 'dangerous' in respect of a test flight of the new shuttle. For example, present ground control facilities would cover only 25 minutes at maximum of a 90 minute shuttle orbit. Worse still there is a yawning gap, exactly where Soviet designers want real time telemetry, during the vital retrofire and re-entry phases over the South Pacific and the Atlantic Ocean/Africa.

Testing the Shuttle

The most dangerous part of the test is the launch phase. There is little or no requirement for human pilot control during this phase and it would therefore be quite acceptable for the shuttle to be launched unmanned. Thereafter it could be remotely controlled to re-enter and land, or, it could be parked in orbit where pilots could join it via a Soyuz launch, and bring it back to Earth at their leisure.

The second most dangerous part of the flight for human occupants, or the most sensitive part of an unmanned flight, is the re-entry and landing phase. Cosmos 1897 south of Cuba has an overview of almost all this phase. It can relay direct to another geosat nearer to the USSR, or it can downlink to Cuba from where data can be transfered to the USSR by either Raduga or Gorizont geosats orbiting at 45 degrees West (these latter geosats have fixed antennas and could not easily track a shuttle directly).

This may sound complex, but it is just what the Americans did for two years with their shuttle flights, relaying via TDRS Tactical Data Relay Geosat 1 to White Sands New Mexico, whence the signal went back up to a commercial comsat and thence down to Houston Ground Control.

It is also significant that the Soviets have stationed a Comship near Madeira, where it can access Cosmos 1897 and also monitor much of the re-entry corridor, relaying information to the USSR via a Gorizont or Raduga geosat.

Anticipating Flight Times

The following factors will probably influence the launch date and time. Overall readiness of the shuttle for launch; daylight at Tyuratam for launch and landing; weekday at Tyuratam (Soviet bureaucrats like their weekends off, so Tuesday, Wednesday or Thursday are most likely days); good weather and wind forecasts for landing area; and a possible need to synchronise with Mir, if they wish to co-orbit – though this latter consideration is unlikely because it savagely restricts the dates to two periods centred on the end of April and the end of June in 1988.

Hearing Shuttle Communications in UK?

The possibilities are very slight indeed, especially if the shuttle only flies one or two orbits before landing, because it will not come in line of sight range of UK. If, however, the flight is of longer duration, communications may be heard on any of the following:

Unmanned Flight
HF 19.955 and 20.004/20.008 MHz PDM beacons and telemetry.

VHF 166.150 approx centre frequency + or – 100 KHz wide band remote control link. 192.04 MHz possible telemetry.

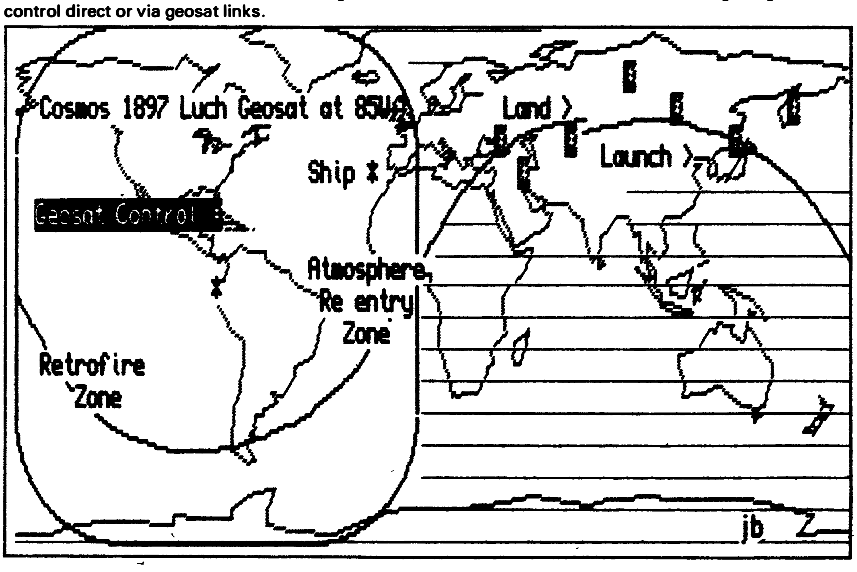
UHF 919.76, 922.75, 925.24 and 926.06 MHz telemetry.

Microwave Downlink; 10 channels spaced at 50 MHz intervals from 10958 MHz channel 1 to 11658 MHz Channel 10 – most likely out of range of UK at all times, but may be audible in South America, Florida and the West Indies.

Manned Flight Frequencies will probably use some of those quoted in the unmanned case above, plus the following voice channels:

121.75, 142.417, 143.625, all FM voice, with 142.6, 143.144, 143.825 MHz. Also FM voice but much less likely to be used.

Possible communications network for single orbit shuttle test, (unshaded areas are in range of ground control direct or via geosat links.



Students Meet Volkov

Soviet cosmonaut Alexander Volkov, a veteran of Salyut 7 and due to visit Mir at the end of this year, met up with six young people in London during April.

The six, five of whom are members of the British Interplanetary Society, hope to represent Britain at the first session of the new International Space University this summer.

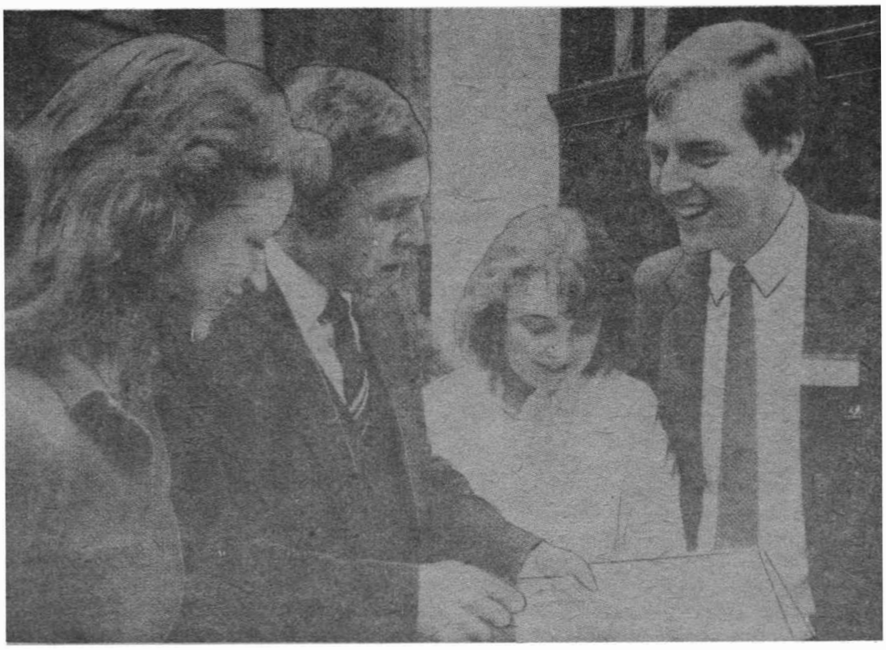
However, only half of the required £33,000 to send the students has been raised leaving a question mark over UK participation in this new venture. The government has so far declined to make any contribution.

Alexander Volkov, who spent two days in London before travelling for a week-long visit to Yorkshire, said that his country was sending 12 students, all funded by the Institute of Cosmonautics, to the University's opening term which is being held in America.

Volkov, awarded the Order of Lenin in 1986 after he took command of an unscheduled return to Earth from Salyut 7 following the sudden illness of the crew's commander Valdimir Vasyutin (***Spaceflight***, January 1986, p.19) told the British students that space activities provided direct economic benefit to the Soviet Union.

"There is nothing more important because it affects the whole country. I don't think space flight is something that can be economised on," he said.

Expressing regret that the UK was the only country still not to have fully sponsored its students for the ISU, Volkov had the following message for Margaret Thatcher: "The only sensible thing to do is listen to the UK scientists . . . and in particular spend money on training youth."



Alexander Volkov in discussion with ISU hopefuls (from left) Angela Bedford, Claire Pinches and Russell Hanigan. The others selected are Jane Deakin, Graham Dorrington and Carol Nairn.

Dunayev: Shuttle Will Fly on Second Energia

Regular *Spaceflight* **correspondent** *Theo Pirard* **received some frank answers when he recently had the opportunity to question Alexander Dunayev, the chairman of Glavcosmos. We begin with comments on the issue of the moment – the first flight of a Soviet shuttle – before the questioning turned to other but equally fascinating areas, such as the next Mir space station and the commercial marketing of Proton.**

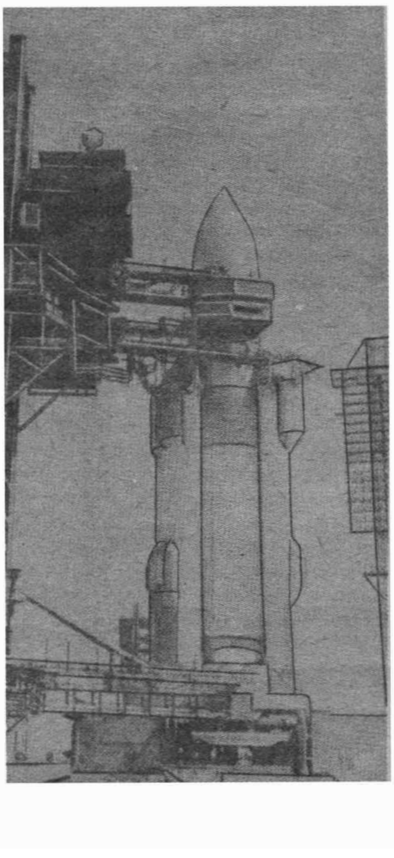
Is it right that you are preparing the launch of a reusable spaceship with the next Energia vehicle?

A. Dunayev: You will not be waiting for long to see this next launch. We are just in the process of finishing all preparation tests at the Baikonur cosmodrome. This will be the second flight of Energia and the only one this year.

You had problems with the first test flight...?

Dunayev: The flight of May 15, 1987 was a success. We were unable to place a payload in orbit because of a ridiculous mistake: the engine of the payload ignited correctly but in the wrong direction. Instead of reaching space, the payload came back to Earth! With the re-usable shuttle this mistake will not happen.

First Energia on the launch pad.



Will the first flight of your shuttle be manned?

Dunayev: Unmanned. We will test our shuttle without men aboard. The spaceship will fly and return to Baikonur in a completely automated mode after two orbits . . . It is specifically an automated vehicle and it will take many years before we will use it with cosmonauts. It is, of course, a very ambitious programme.

How will you enlarge and improve the Mir complex?

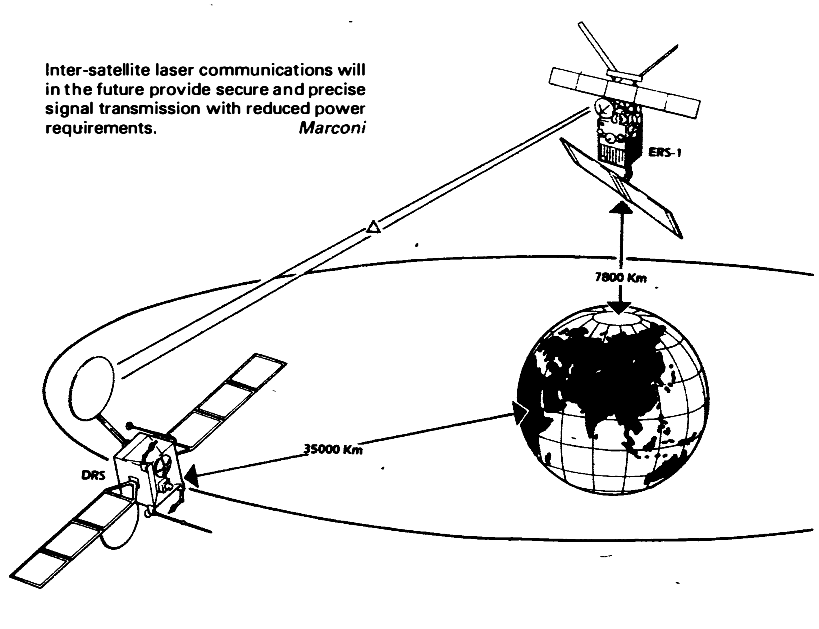
Dunayev: Three international flights are scheduled this year: with a Bulgarian cosmonaut, during a 10-day mission starting on June 21, with an Afghan cosmonaut, in August, and with a French astronaut, in November, for a one-month duration mission. Just before this third international space flight, we plan a Kvant-type (but longer) module launch for docking on the front of Mir, with transfer to a lateral docking port.

Can you describe this module and the following module?

Dunayev: The next module will be an energetics module, offering a more

Lasers Will Open Up Satellite Communications

Inter-satellite laser communications will in the future provide secure and precise signal transmission with reduced power requirements. *Marconi*



A British firm is carrying out initial studies and development on the use of lasers for satellite communications under a £½ million contract from the Royal Aircraft Establishment, Farnborough.

Conventional microwave links between satellites are possible but the use of laser optics offers a number of significant technical advantages. Most important of these is the high directivity of the laser transmission, producing a confined, narrow beam focused on the target satellite rather than the broader beams typical in microwave systems.

Apart from the security advantages that these narrow beams offer, the fact that more of the transmitted signal is focused onto the target satellite means the receiver and transmitter on the spacecraft can be smaller and consume less valuable electrical power.

Marconi Space Systems' contract will study the various technical options for optical receivers and transmitters and select the most suitable system. Demonstration hardware will then be developed to illustrate the system's effectiveness in the laboratory.

The first demonstrations of these techniques in space may be on the European SAT 2 spacecraft scheduled to fly in the early 1990's. By the mid 1990's it is hoped that pairs of satellites will routinely be communicating by laser beam using Marconi-supplied hardware.

The RAE contract recognises the importance of this development in space communications and is aimed at securing a leading UK role in this market. Marconi is making a substantial contribution to the cost of the development work.

Dunayev Interview

Continued from previous page.

comfortable and very convenient environment for Mir crews. Subsequent modules will be launched every five months . . . in early 1989, a technology or engineering module. For the second half of 1989, a Priroda module for remote sensing observations. For 1990, a scientific research module or the Medilab element. It is our plan to achieve the complete assembly of Mir-1 by mid 1990.

What about Mir-2?

Dunayev: We are planning Mir-2 after 1994-1995. We are just starting design studies. We will use the Energia vehicle to launch the main element of this next space station.

Could you make a statement on the Proton marketing problems?

Dunayev: The main problem we have had is that the United States is not allowing any spacecraft having American components to be sent to the USSR. We had contacts with several companies interested by our launch services but these contacts are suspended at present due to the fact that the US authorities are not giving the permission for the importation of a satellite to a Soviet cosmodrome. We believe that the reason for such a negative attitude concerning the launch of any spacecraft with American technology is more political than economical and technical.

Following the recent launch of an Indian satellite by Proton what are your future plans?

Dunayev: We want to continue this cooperation with a developing country, hopefully with the launch of the second Indian Remote Sensing satellite. We have already had discussions on the next generation of satellites. The Indians are preparing a side-looking radar observation satellite and we are discussing with India how to co-operate on the development of this new type of remote sensing spacecraft. Our purpose is to get the launch contract for the second.

Your speciality is space transportation?

Dunayev: No, because we can also offer services with manned spacecraft and microgravity opportunities. At the present time, we can meet foreign demands, very completely, very quickly, with space transportation, and with opportunities for microgravity experiments. In the future, depending on the international space business, we will offer our spacecraft for communications, broadcasts and remote sensing operations.

What about your marketing for microgravity opportunities?

Dunayev: We already have customers for experiments in the Mir station and with the Photon capsule. An American company, Payload Systems Inc, will fly pharmaceutical research equipment onboard the Mir complex. A European customer is the German Kayser Threde firm for microgravity experiments in Photon capsules. We are continuing negotiations with other companies, especially in Europe.

Inmarsat Extends Order

Inmarsat has ordered a further Inmarsat 2 communications satellite from the Space and Communications Division of British Aerospace.

The contract is for Inmarsat 2 F4, the fourth satellite to be ordered from British Aerospace. In April 1985 Inmarsat placed an order for three satellites, valued at US $150 million, with an option to supply a further six.

Inmarsat 2 F4 with the other three satellites, will together comprise Inmarsat's second generation space segment providing a global maritime mobile communications service.

Arianespace Plans Two Launches in May

Two flights of the European-built Ariane rocket are planned for this month (May), including the first Ariane 4.

Launch campaign for flight 23 carrying the Intelsat V F13 communications satellite began on April 1, with third stage erection on April 12. The target launch date for this Ariane 2 vehicle is May 11.

On March 24 the launch campaign for flight 22, the first Ariane 4, was resumed with third stage erection taking place on April 1. Launch is scheduled for the end of this month.

* * *

On March 11, at 11:28 pm (UT), Arianespace successfully launched two telecommunications satellites, Spacenet III, for the American company GTE Spacenet, and Telecom 1C, for France.

The spacecraft were launched by an Ariane 3 from the ELA 1 launch site in Kourou and injected into a geostationary transfer orbit.

This launch contributed to the installation of the first satellite radio positioning system, operated by the US firm Geostar Corp. The reception capacity was put into orbit on the Spacenet III satellite.

Following the launch, Arianespace chairman Frederic d'Allest said: "After the sucessful launches of Ariane flights 19 and 20, this further performance encourages Arianespace to have full trust in the increased launch rates it has set as its goal.

"Taking into consideration the enhanced industrial and operational potential now in place, Arianespace is close to achieving its objective of eight launches this year. The company will remain extremely watchful and rigourous in their execution."

On March 13, at 12:33, the Telecom 1C apogee kick motor was ignited at the fourth apogee passage, and its solar panels were deployed as scheduled the following day.

After ignition of the Spacenet III motor, on March 15 at 5:58 pm, its solar panels were deployed during the night.

* * *

Arianespace has been awarded the launch contract for Germany's TV-SAT 2 direct broadcast satellite which will be placed into geostationary transfer orbit (GTO) in spring of 1989 by an Ariane 4, the newest and most powerful version of the European launch vehicle. Topped with a SPELDA external load bearing dual launch unit, the rocket will be launched from the ELA 2 launch complex.

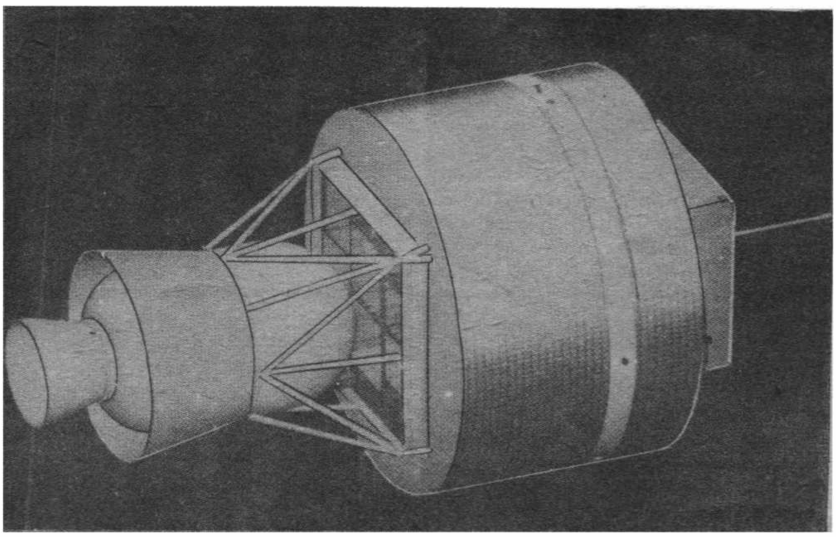
The order gives Arianespace a cumulative total of 64 launch contracts, with 42 outstanding.

Anglo-Chinese X-ray Satellite Study

A Computervision CISMedusa CAD/CAM system is playing a key role in satellite design at the British National Space Centre's Rutherford Appleton Laboratory

It is currently being used in connection with a joint Anglo-Chinese project for designing an X-ray satellite (CHIXSAT).

The CHIXSAT project involves the design of a spacecraft (see illustration) incorporating a set of seven detectors which are to be used for imaging stars in the X-ray region of the spectrum.



Shuttle Crews Announced

NASA has announced the crew members selected for three forthcoming Space Shuttle missions. This concludes crew selection activities planned prior to the resumption of Shuttle flights in August, *writes Roelof L. Shuiling.*

Michael L. Coats.

The January 19, 1989 flight of Discovery will be commanded by Capt. Michael L. Coats (USN) who flew as pilot on 41D. The pilot will be Col. John E. Blaha (USAF) who will be making his first flight. Col. James F. Buchli (USMC) will make his second flight as mission specialist having flown on 51C. Making their first Shuttle flights will be mission specialists Col. Robert Springer (UISMC) and James P. Bagian.

STS-30 will be launched on April 27, 1989 on Atlantis with Capt. David M. Walker (USN) in command. Capt. Walker flew as pilot on the 51A mission. The pilot will be Col. Ronald J. Grabe (USAF) who also flew on 51J. Norman E. Thagard, will be making his third flight as mission specialist, having flown on STS-7 and 51B. Mary L. Cleave will make her second mission specialist flight after having flown on 61B. Maj. Mark C. Lee (USAF) will make his first flight as mission specialist.

The STS-31 mission will be launched on Discovery June 1, 1989 under the command of Col. Loren J. Shriver (USAF) who flew as pilot on 61B. The pilot will be Col. Charles F. Bolden (USMC) who flew as pilot on 61C. Steven A. Hawley will make his third flight as mission specialist having previously flow on 41D and 61C. Capt. Bruce McCandless (USN) and Kathryn D. Sullivan will both be making second flights as mission specialists, McCandless having flow on 41B and Sullivan on 41G.

• **New Shuttle Manifest** – *see p. 197*

INTERNATIONAL SPACE REPORT

SATELLITE DIGEST – 212

Robert D. Christy

Continued from the April 1988 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1908, 1988-1A, 18748
Launched: 0742, 6 January 1988 from Plesetsk, by F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 635 x 664 km, 97.78 min, 82.52 deg.

COSMOS 1909-1914, 1988-2A-F, 18788-18793
Launched: 0354, 15 January 1988 from Plesetsk by F-2.
Spacecraft data: Each satellite may be spheroidal in shape, about 1 m long and 0.6 m diameter, and with mass approx 100 kg.
Mission: Single launch of six satellites, possibly to provide tactical, point to point communications for troops or units in the field.
Orbit: 1385 x 1412 km, 113.81 min, 82.61 deg (lowest), 1412 x 1414 km, 114.12 min, 82.61 deg (highest).

PROGRESS 34, 1988-3A, 18795
Launched: 2252*, 20 January 1988 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried equipment and consumable supplies to the resident crew of Mir. It docked with Kvant's aft-facing hatch at 0009, 23 January 1988.
Orbit: Initially 185 x 258 km, 88.87 min, 51.65 deg then by way of a 242 x 271 km transfer orbit to a docking with Mir/Kvant in an orbit of 334 x 355 km, 91.37 min, 51.63 deg.

COSMOS 1915, 1988-4A, 18809
Launched: 1120, 26 January 1988 by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 196 x 375 km, 90.27 min, 72.88 deg.

METEOR 2 (17), 1988-5A, 18820
Launched: 1102, 30 January 1988 from Plesetsk by F-2.
Spacecraft data: A cylinder with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at one end. The length is probably about 5 m, diameter 1.5 m and mass around 2000 kg. Stabilisation is by the use of momentum wheels.
Mission: Meteorological and remote sensing satellite.
Orbit: 938 x 960 km, 104.10 min, 82.52 deg.

USA 29, 1988-6A, 18822
Launched: 0557*, 3 February 1988 from Vandenberg by Atlas.
Spacecraft data: Irregular cylinder with a single solar panel at right angles to one end. The length is about 6 m, and the diameter approx 2 m, and the mass is around 700 kg.
Mission: Defence Meteorological Satellite Programme vehicle, sending back weather images and other data for use by the US DoD.
Orbit: 820 x 829 km, 101.45 min, 98.77 deg.

COSMOS 1916, 1988-7A, 18823
Launched: 1215, 3 February 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 171 x 361 km, 89.85 min, 64.88 deg, manoeuvrable.

Marconi Studies Titan Probe

A British firm is leading design feasibility studies for a spacecraft which is destined to make an historic journey into space to explore Titan, a moon of Saturn. A £250,000 contract for the design study was awarded to Marconi Space Systems recently by ESA (the European Space Agency).

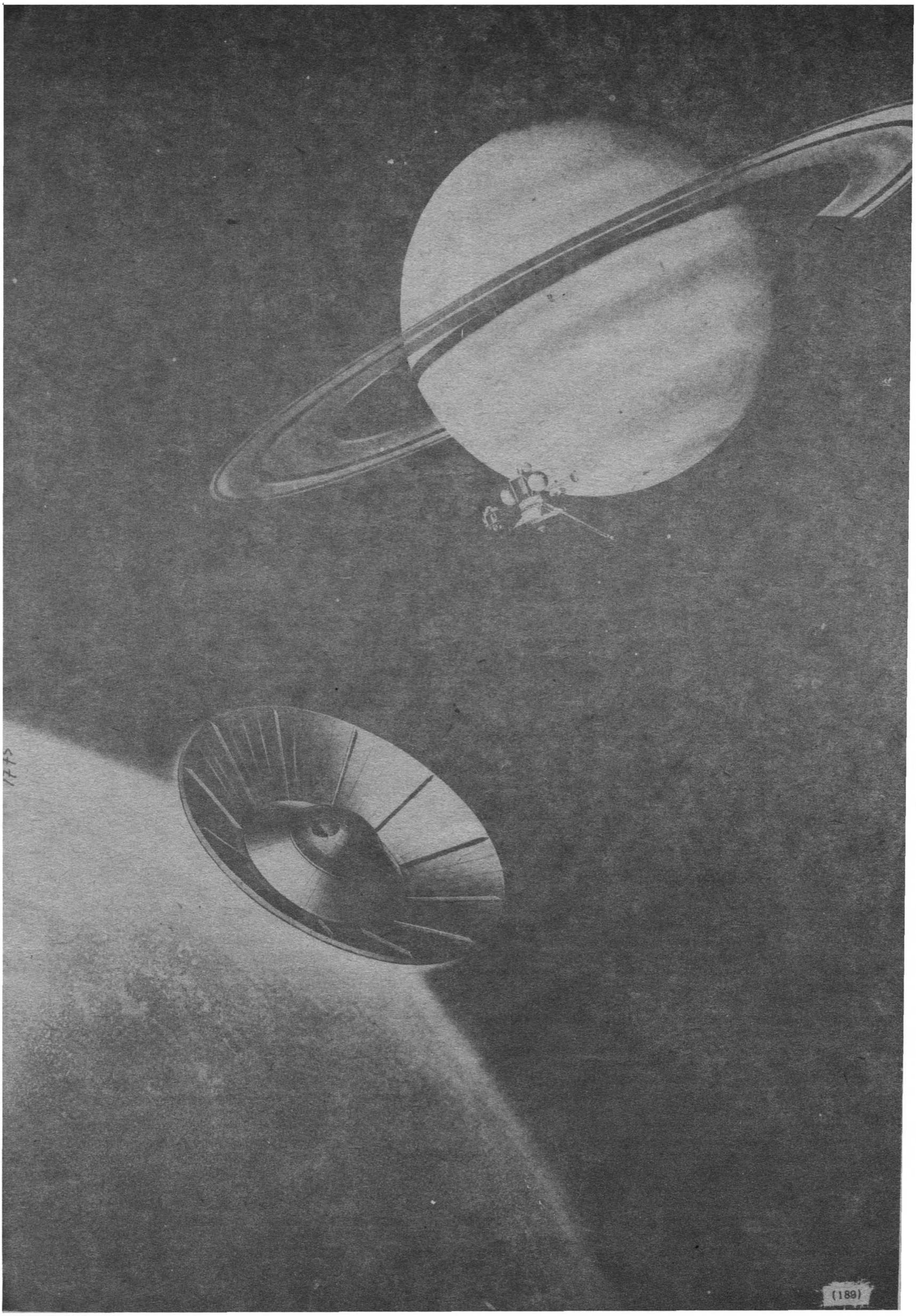
ESA's Titan probe will partner a NASA satellite, known as Cassini after the celebrated 17th century astronomer, on its eight year journey into space. During its voyage the spacecraft will fly past and investigate Jupiter and at least one asteroid. On reaching Saturn, and insertion into Saturn orbit, the Titan probe will be targetted and separated from the NASA Saturn orbiter.

The NASA element will continue to orbit the planet over a four year lifespan, while the Marconi designed Titan Probe will descend towards the moon's surface. During its descent, the probe's ten scientific instruments will make detailed measurements.

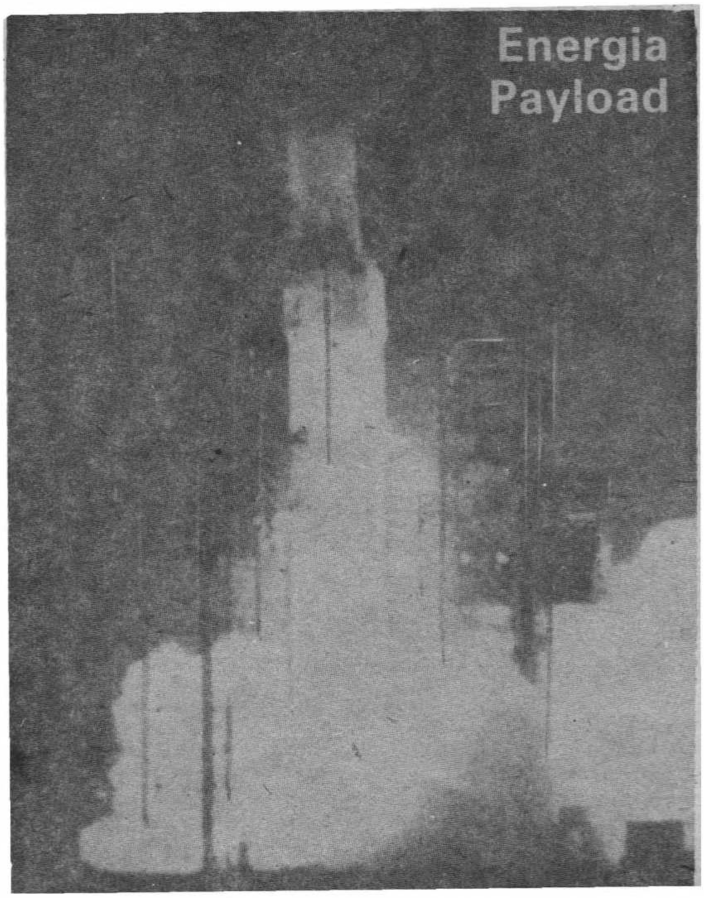
Since Titan is the only body in the solar system to have an atmosphere composed chiefly of nitrogen, similar to Earth, the experiments will provide an insight into how Earth looked before the creation of life.

The chemical "soup" of Titan's atmosphere contains all the ingredients for the start of life and it is thought likely that amino acids, fundamental parts of living systems on Earth, have already been formed. However, there is little "free" oxygen on Titan and this, combined with the extreme cold, leaves little prospect of life being found there.

The Cassini satellite, pictured opposite with the Titan probe in the foreground, is scheduled for launch in 1996.



CORRESPONDENCE



Sir, In connection with Tony Devereux' letter on Energia's payload (***Spaceflight***, February 1988, p.70) I would like to make the following remarks.

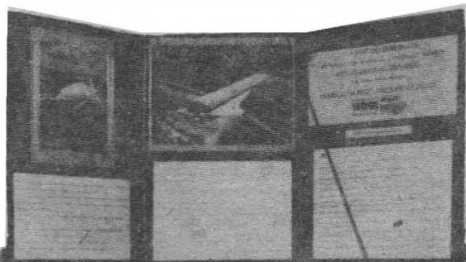
There seems to be photographic evidence that the Energia 1 payload cannister employed an engine during lift-off. In the accompanying enlarged section of a photograph showing the launch of Energia 1, the booster is seen from its right side. One can just make out the nose cone of the payload cannister and a reflection from the launch pad's illumination. At the bottom of the cannister is a bright plume, which, in my opinion, cannot possibly be from Energia's boosters.

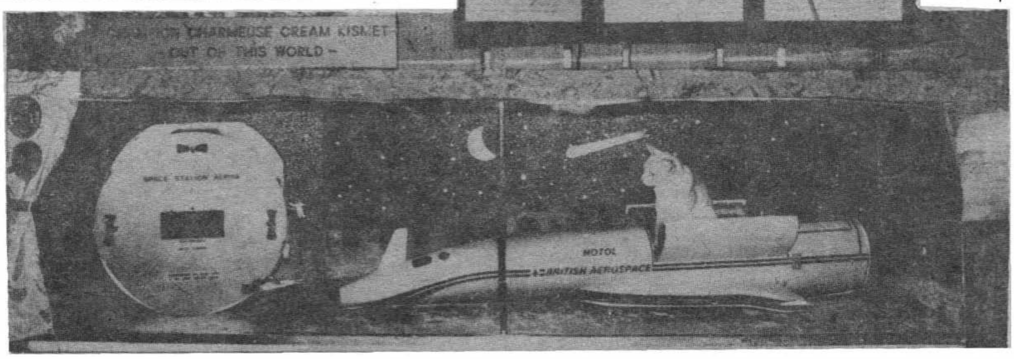
On the connection between Energia's payload and the name of the booster, as Saunders B. Kramer suggested (***Spaceflight***, November 1987, p. 37), I would like to express my doubt that there is any. The last time a Soviet booster was named after its payload was in 1965, with Proton. Besides, I am not aware of a series of Soviet 'Tsyklon' satellites, launched by a booster of the same name.

Moreover, an alternative name for Energia was discussed within Glavkosmos before the first launch. That name was 'Grom', Russian for thunder. Were the name-payload connection maintained, and Energia had flown named Grom, one could have concluded the booster had placed an explosive device in orbit! With Energia, the name has obviously more bearing with its mighty performance, not its payload.

LUCIEN VAN DEN ABEELEN
The Netherlands

Out of This World





Sir, In recent years, I have exhibited my champion female cream Burmese – Champion Charmeuse Cream Kismet – very successfully in a space flight theme pen display. During 1987 a special display featuring Hotol was very well received indeed – so well that I am still showing the display at certain cat shows in 1988. Many people attending these shows know very little about space flight so I am spreading the word.

The whole display took over a year to make. The model of Hotol took six months to make, working from photographs of models made for wind-tunnel testing and from "artists'impressions" published in *Spaceflight*.

Hotol was made of dense polystyrene stuck together with special adhesive. After arriving at a suitable shape the outline was further detailed by using a Stanley plane, various files and sandpaper. The wings were made separately in a similar fashion. The body was then treated to three coats of emulsion paint before being sprayed to a brilliant white finish. The "livery" was achieved using red, white and blue plastic tape with badges and logo, cut from magazines, for British Aerospace and Rolls Royce.

I have modified the model three times to conform with alterations introduced by British Aerospace.

The factor which fixed the scale of the model was the requirement for cargo bay doors large enough for a Burmese cat to lie on during a cat show. The model is to an approximate scale of 1:42 making it 5 feet long. This is too long for the standard 4 foot long exhibition pen at cat shows – hence the need to make our own special pen, which is 8 feet long and very impressive with sliding perspex front doors.

For the purpose of the display, Hotol is to rendezvous with Space Station Alpha at its front facing air-lock. Space Station Alpha houses the obligatory litter tray with access from the left-hand side! The space-suited maintenance crew of two can be seen to the right of Space Station Alpha. A starry background is evident with the whole pen set in low Earth orbit. Panels on the top of the pen give an indication of what Hotol will do – together with the nameplate for the cat itself.

The scene is set for the year 2005 – I wonder .....!

JOHN W. BURLEY
Devon, England

CORRESPONDENCE

Spaceplane Recommendation With Aerial Refuelling

Sir, It is now time to begin design definition of a new type of manned launch vehicle for Earth-to-Orbit (ETO) operation to replace the current space shuttle. In the aftermath of the loss of Challenger, it has become public knowledge that the final shuttle design was driven by a series of political compromises, and the bottom line was the number of dollars available from Congress.

Therefore, this final cost-limited design resulted in a very fragile vehicle whose structure was shaved of every possible extra gramme of weight, and whose engines were pushed beyond their design limits in order to squeeze out the last possible increment of performance. Unfortunately, this has given NASA a manned Space Transportation System that is too fragile, too labour-intensive, too failure-prone, too valuable, and too few to dare use for the routine launching of payloads that do not absolutely require manned operation. Now, with the wisdom of hindsight, it is time to propose an entirely new concept in launch vehicles to ensure that never again will NASA and the United States be denied routine access to space.

Political and funding considerations are certainly beyond the scope of this item and must be left to others to resolve. A proposed interim Shuttle-2 vehicle [1] would bridge the gap between the current shuttle and the National Aerospaceplane (NASP). The Shuttle-2 concept proposes a vertical-launched all-rocket propulsion vehicle, but it would be capable of single-stage-to-orbit aircraft-type operation, and its systems would be designed to operate with wide safety margins. This is certainly a step in the right direction and would obviously be very valuable as an interim technology demonstration vehicle. However, while alleviating some of the worst shuttle problems, it still suffers from many of the current shuttle limitations.

After careful consideration of all of the above, I would propose adoption of the following points as basic design criteria for a new manned ETO vehicle.

- The basic design of the vehicle should be similar to that of the National Aerospaceplane, incorporating as many aircraft-like operations as possible to reduce operating costs and to greatly increase safety and reliability.
- It should be a 100 per cent reusable single-stage-to-orbit vehicle; nothing should be jettisoned or expended in flight except fuel.
- It should use turbojet/turbofan engines, for takeoff and cruise to Mach 3; ramjets for Mach 3 to Mach 6; scramjets for Mach 6 to Mach 18; and rocket propulsion for the final boost from Mach 18 to orbital velocity of ~ Mach 25.
- It should be designed for horizontal takeoff and landing, from as large a number of military and commercial airports as possible, and require a minimum amount of ground-handling facilities and personnel.
- It should be designed for routine mid-air refuelling after takeoff as a means of greatly increasing payload to orbit and reducing airframe size and weight.
- Engines should be routinely operated well below their rated thrust levels, as is done in commerical jet liners, and never allowed to exceed 80 per cent of maximum rated thrust except in an emergency.
- Crew ejection seats or escape pods should be designed in from the beginning.

The following important considerations led to the above-mentioned points: NASA should not design another manned spacecraft that requires vertical launch because it is simply too dangerous and unforgiving, and the technology is now available that makes it unnecessary.

In a vertical launch the vehicle has no aerodynamic lift or stability while balancing precariously on its exhaust, and it must rely strictly on brute force thrust to gain altitude. Any engine or control problem during this critical period could prove catastrophic. The instant the vehicle begins to rise it is totally committed, and the crew can do little or nothing if a major problem arises. We all have seen too many expendable launch vehicles drop back on the pad and explode or veer out of control moments after launch. Challenger certainly proved that this will also happen sooner or later to any manned launch vehicle.

In a horizontal launch all engines can be throttled-up slowly, resulting in a gentle take-off roll with aerodynamic stability and lift, plenty of time to abort a take-off and drop back on the runway, and minimal shock to the system. Launches should no longer put undue stress or vibration on the vehicle or any of its systems, and obviously no components must ever again be routinely operated at or even near their redline values as is currently done with the shuttle main engines.

Routine airline operations could never have become routine or economical if aircraft had been forced to use vertical launch, drop solid or liquid-fuel boosters, or even flyback boosters, drop tanks, etc. Obviously impact points would seriously constrain possible take-off sites.

Engines should be all liquid fuel. Engine definition studies and even advanced testing is already well underway at various NASA centres. Fuel options include hydrocarbon (liquid natural gas or JP-4) or LH_2, or both, along with ram air for the turbo/ram/scramjet; LH_2 and LOX would be the logical choice for the rocket propulsion system.

Since the spacecraft will take-off, fly and land like an airplane, it may as well adopt a payload and range-extension technique that has been in constant and routine use by the US Air Force for decades; that is mid-air refuelling. It has been routine practice, at least since Viet Nam, for Air Force bombers and fighter bombers to take-off with a full load of ordnance (bombs) and only a partial load of fuel (so as not to exceed gross take-off weight limits on the airframe), and then top up fuel tanks from a tanker aircraft while cruising at subsonic speeds around 30,000 feet altitude. This is a safe, well-proven, routine operation, and if applied to the new launch vehicle, could greatly increase payload to orbit and greatly reduce structural size and weight over a vehicle not designed for aerial refuelling. A possible scenario would be to take-off with a full load of LH_2 and LOX and only a partial load of hydrocarbon fuel, and then aerial refuel with additional hydrocarbons. This would be the most efficient because of the much greater density and thus weight of hydrocarbons, as compared to LH_2; simply let the tanker aircraft lift all this weight of fuel off the ground.

In order for this vehicle to achieve stable extended flight at subsonic speeds, it is recommended that hydrocarbon fuel be considered for the turbojet/ramjet propulsion system (and also because of mid-air refuelling experience), while LH_2 can be used for the scamjet and final rocket boost to orbit. If LH_2 were used exclusively, it would require very large fuel tankage structure due to its low density and high volume, resulting in an excessively large fuselage and therefore a low lift/drag ratio of the airframe, which during the subsonic cruise portion of the flight profile would not have the benefit of high-speed propulsive lift.

A major advantage of this type spacecraft is that it could take-off from any convenient runway and fly into any inclination orbit from polar to equatorial. It could eliminate energy-expensive dog-leg upper manoeuvres currently necessary for satellites launched into geosynchronous orbit, by flying subsonic south to the equator and turning east while still in the atmosphere, refuelling in mid-air and then accelerating to low Earth-orbit at zero degree inclination. Thus, injection of geosynchronous satellites would require a smaller, lighter upper stage since fuel expended in achieving zero degrees inclination would have been replenished by the tanker aircraft.

Another major advantage of this type spacecraft is obviously safety. There is no need for an "all-up" test on the first, or any flight, as was necessary with the shuttle. Flight testing can proceed step-by-step, achieving faster speeds and

higher altitudes in each test until enough confidence is reached to achieve orbit. A relatively safe abort would be possible at any time up to orbital insertion. Mission rules should require that enough hydrocarbon fuel remains in the vehicle's tank after orbital insertion so that after a standard type retroburn and unpowered re-entry, descent, and aerodynamic deceleration to below Mach 1, the turbojets could be restarted, enabling cruise and rendezvous with another refuelling tanker aircraft if necessary.

Refuelling would give the craft essentially a world-wide landing footprint and allow a powered landing at any desired runway for direct delivery of a payload returned from space, and also eliminate the dangerous one-shot dead-stick landings that the shuttle must make. This would also eliminate the need for a re-entry window, since re-entry could be initiated anytime, anywhere along the orbital track if an on-orbit emergency occurs; again a great increase in safety.

NASA Ames, Langley, and Lewis have already completed extensive studies and actual prototype testing of the aerospaceplane-type engines mentioned above, and MSFC has begun studies of the Shuttle-2 engines. Much information has already been published. All of the points discussed above, except one (aerial refuelling and its advantages), have appeared repeatedly in the open literature especially in recent issues of *Aerospace America*. As far as is known, however, the concept of aerial refuelling the spacecraft originated with the author.

DALE M. KORNFELD
Huntsville, USA

Reference

1 *Aviation Week & Space Technology*, December 1, 1986, p 30.

Space Exploration Better Than Space Militarisation

Sir, The recent emphasis in ***Spaceflight*** correspondence has been on UK Space Funding. Whilst I agree with the sentiments and reasoning of these letters, I suggest that an even more important aspect of space flight is emerging; and that is the increasing use of space by military organisations, and in particular by the Strategic Defence Initiative.

There are reports that after 1990 the shuttle will be largely devoted to military use, and it is possible to develop very bleak scenarios for space flight. When these scenarios are considered, the concerns of UK space funding pale into relative insignificance.

I therefore believe we should welcome the recent policy decision by President Reagan to plan a Mars mission and a Moon base. It means that the USA will not be devoting all its space resources to the development of SDI and that other interests will have a powerful influence on restraining the military interest.

IAN B. DARNEY
Bristol, UK

Soviet Crew Surprises

Sir, Late 1987 left many space analysts scratching their heads with the surprising crew announcements made by the Soviets for upcoming MIR missions. I thought a brief review might clear up some of the confusion.

Ever since the failed docking attempt of Soyuz T8 with Salyut 7 in April, 1983 and the Soyuz T-10A launch pad abort of September 27 the same year, many analysts had speculated that a new crew, comprising two men related to those incidents Vladimir Titov and Alexander Serebrov, was due for a long duration stay on Salyut 7 or its follow on Salyut 8, renamed Mir. Indeed the men were said to be the backup crew of Soyuz T13/14 flight in 1985.

In the first of a string of surprises the Soviets announced Leonid Kizim and Vladimir Solovyov as the prime crew for Soyuz T-15. This choice seemed to hinge on the need for an experienced Salyut 7 crew to close down that station and retrieve experiments. Who better than Kizim and Solovyov both men establishing records for long duration flight and accumulated EVA time on Salyut 7 in 1984.

The backups for this mission were once again Titov and Serebrov. Surely this meant that their time had come to try again.

As 1986 drew to a close it seemed inevitable that the two men would fly to Mir for a new attempt at the world record exceeding 237 days by as much as two months. In late January 1987 a new crew was announced and this too was a surprise. Yuri Romanenko and a rookie Alexander Laveikin was chosen to fly to Mir. It was disclosed that Laveikin had never trained in a backup role before his flight. In 1988 the reason became clear, they were the original backups to the prime crew of Titov and Serebrov. No one could explain why the two had been bumped once more. It seems that the two were once more separated and became members of different crews in training for future flights.

In November 1987 a photo showing what is assumed to be the prime crew for the upcoming Soviet-Bulgarian joint mission was released. The crew consisting of Vladimir Lyakhov, Alexander Alexandrov and the elusive Alexander Serebrov. If they were to be the prime crew then it is assumed that they would have flown to Mir aboard Soyuz TM5 on June 21, 1988. This was not to be the case.

Shortly after, two crews were announced for the upcoming Soyuz TM4 flight comprising Vladimir Titov, Musa Manarov and Anatoly Levchenko, the surprises here were that Serebrov was missing, but he was presumed to have joined the joint Soviet-Bulgarian flight on Soyuz TM5, and rookie Anatoly Levchenko had replaced the expected doctor Poliatkov. The backup crew was named Alexander Volkov, Alexander Kalery and Alexander Shukin.

Less than a week later on December 21, 1987 the Soviets brought out their Soviet-Bulgarian crews for a press conference, the prime crew consisting of Victor Savinyhk, Anatoly Solovyev (rookie) and Bulgarian Alexander Alexandrov. The Soviet crewmembers were the backups to the Soyuz TM3 mission last summer.

The next announcement was another surprise, the backup crew would be lead by Vladimir Lyakhov with Krasimir Stoyanov of Bulgaria as researcher and Andrei Zaitsev a rookie replacing Serebrov. If indeed Serebrov was part of the prime crew as the photo mentioned above suggested then once he was removed it seems that Lyakhov was also bumped for Anatoly Solovyev. The reason for Serebrov's removal from Soyuz TM5 is still unknown but I am sure we will see him before this year is out visiting Mir, possibly in relation to the upcoming joint Soviet-French flight in November. The surprises are not over yet.

LEE CALDWELL
Toronto, Canada

Unmanned Supply Shuttle : Manned Spaceplane

Sir, The Soviet shuttle maybe a more basic vehicle than previously we have been led to believe [1]. If this is the case what is going to be the manned spaceplane and where is it?

I would first like to make a logical speculation about how a 90 ton basic shuttle docks with a 40 ton manned space station. It does not dock, but stands off Mir by about 2 km, (see the Progress 32 simulation reported in ***Spaceflight***, March 1988, p.114). The payload in the shuttle cargo bay, consisting of one station module attached to a transfer unit, is released from the bay, proceeds to carry out a routine approach to the Mir complex and docks. The shuttle can then return to Earth. Other flights would have the transfer unit returning to the shuttle for retrieval and return to Earth and likewise would return Mir modules for refurbishment and upgrading.

As pointed out [1] it could be some years before a manned version of the shuttle would be ready. However, this does not appear to square with other evidence which indicates a man-

ned spaceplane in 1989. How are these differences to be resolved?

Although a small spaceplane has often been mentioned, the scarcity of information about the vehicle could mean that it does not exist. A requirement for something better than updated 50's and 60's technology is obvious, despite the ingenious Soviet use of it. The conclusion is that this is a military project on which there is tight military security with few cosmonauts even aware of the project, even though they may know that something is going on. I would also hazard to suggest that the first flight will be from the Northern Cosmodrome at Plesetsk into near polar orbit by two military test pilots and dramatically announced (after a successful launch) to the world press as the first manned orbital polar flight.

R. HARVEY
Portsmouth, UK

Reference
1. *Flight International*, March 11, 1988.

Manned Shuttle : Supply Launch Vehicles

Sir, When a manned version of the Soviet shuttle will be tested is unclear, though it seems likely the USSR will attempt to have it fully operational around 1992. In my opinion it will act as crew transporter, crew accommodation/ biological laboratory and emergency Earth-return vehicle all in one for the proposed Mir 2 space station. It will remain attached to the 100 tonne core module for periods of four months before crew rotation and thus leave more of the core module space for other equipment.

Concerning the launch vehicle, the total re-useability of Energia would seem to be in doubt given the little saving made in recovering the liquid propellant fuel tanks for example. However, the recovery and re-use of its first and second stage engines would appear thoroughly economical and plausible given their greater complexity and smaller size. Such engines would probably be similarly re-usable on the SL-16 booster.

Looking in more detail at the SL-16 booster, one of its uses may be indicated by two of its recent launches, Cosmos 1871 and 1873. It seems possible that these were tests of a new Progress feighter based on the 'heavy Cosmos' design, such as Cosmos 1443, which may be partially recoverable and re-useable itself. Such a 15 tonne fully loaded vehicle would be employed to deliver equipment, stores and fuel to the Mir and Mir 2 space stations in the future.

PAUL J. MANT
East Sussex, UK

Mir Communications

Sir, I found John Branegan's report (***Spacelfight***, March 1988, p.108) on listening to Mir communications very interesting indeed and I hope he can be persuaded to contribute further articles to the magazine.

As further reading on the subject I would like you to send me the October 1987 and April 1988 issues of ***Spaceflight***, for which I enclose a cheque for four pounds. Many thanks.

A.M. PARRY
Cheshire, UK

Ed. *Readers interested in practical techniques for tuning into Soviet space communications may like to know that copies of the issues containing John Branegan's series of three excellent articles, 'Listening to the Cosmonauts' (October 1987), 'Mir Communications in 1987' (March 1988), and 'Keeping Track of Mir' (April 1988) can still be obtained (price £2.00 each, including postage) from the* **Spaceflight** *office at the address given on the contents page. Please make cheques etc. payable to the British Interplanetary Society.*

Word Origin

Sir, I was interested to see the use of the word 'Russlish' in J. Branegan's fascinating analysis of space station downlinks (***JBIS***, Vol. 41, No. 3, March 1988). I was under the impression that I was the inventor of this monstrosity (*2010: Odyssey Two* – Chapter 29). Or has it a still earlier, and even more disreputable, origin?

ARTHUR C. CLARKE
Colombo, Sri Lanka

Mir's Multiple Docking Unit

Sir, "Why a second docking drogue", asks Lee Caldwell (***Spaceflight***, November, 1987, p.369). In trying to seek an explanation, I would like to offer some (speculative) thoughts.

I think the second drogue is a back-up, in case the first one is damaged. It is likely both drogues are dismountable.

A Soviet drawing showing the Salyut 7 Cosmos 1443 complex gives a hint of the techniques probably employed on Mir and its modules. Tom van der Horst, builder of model Soviet spacecraft, called my attention to this.

The docking equipment on Cosmos 1443 is shown to be much bulkier than the Soyuz's, yet they were known both to use the same system. It seems, however, Cosmos modules are equipped with both active and passive docking mechanisms. The extra room this takes up would explain the longer docking tunnels shown on Kvant and the drawing of Mir's next module. Once a module docks with the front docking unit of Mir, the hatch is opened and the module checked out and activated. The active part of the docking unit is then removed. Subsequently the module is transferred to a side port using Ljappa.

Later, the module can be separated from Mir and function as a free-flier. Once servicing is necessary, a Soyuz could fly to it and dock, as the module retained the passive docking unit.

The Mir multiple docking unit has already been recognised as the single most important part of the station and the assembly sequence of adding modules calls for frequent use of the forward docking drogue. Should this one day be damaged or become inoperative, it could endanger the continued use of the station.

So, I believe a back-up drogue was installed in the station itself. As a lot of assembly-disassembly work is envisaged operating the multiple docking unit anyway, so the back-up drogue installing should not pose any problems. Moreover, a drogue cannot be brought into the station should problems develop, as it does not fit through the 80 cm hatches used in Soviet manned spacecraft.

LUCIEN van den ABEELEN
The Netherlands

Imaging Neptune

Sir, A minor numerical error has been detected by myself in your recent article about the future Voyager 2 encounter "Imaging Neptune", (***Spaceflight***, November 1987, p.390). It was there mentioned (column 3, line 24) that "the maximum rate is 175 microradians per second: only one-tenth of the hour hand of a clock!" Actually, since the hour hand on a clock is moving at 145.444104 microradians per second, the correct conclusion is that the maximum rate of 175 microradians per second is 1.2 times as *fast* as that of the clock's hour hand.

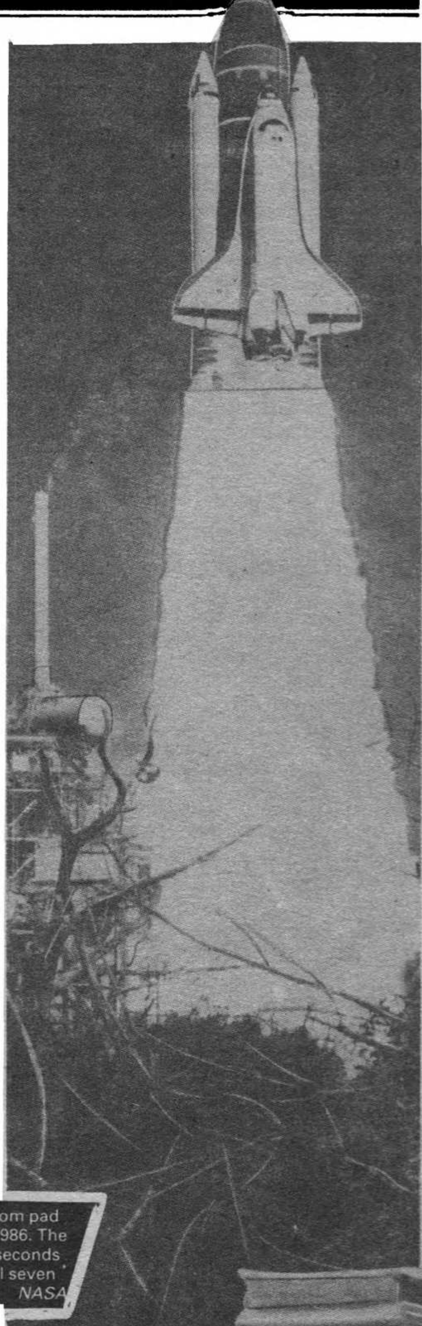
YARON SHEFFER
Texas, USA

Ed. *We now have the hour and minute hands of our office clock appropriately labelled!*

Challenger Tragedy

Sir, Some fellow members in the British Interplanetary Society are familiar with my extensive work on the Challenger space shuttle accident and I thank them for their kind letters. I had hoped to share a synopsis with fellow members in early 1987. However, at the time, I began to discover that the "sequence of events" from lift-off was in error, and my work continued. My final results are summarised below.

ALI F. ABUTAHA
Virginia, USA



Challenger lifts-off from pad 39B on January 28, 1986. The orbiter exploded 73 seconds after launch killing all seven astronauts on board. *NASA*

Study Cites Technical Mistakes

In June 1986, I carefully reviewed the official reports and discovered negative safety margins, excessive lift-off loads and other specific faults. Since potential sources for these disparities were exonerated in the official reports, I attributed the anomalies to the effects of "roll out and sharp left turn" to Pad 39B. Further examination revealed other shortcomings. Roll out was not the dominant culprit, though it was a vital matter.

Eventually I was able to establish a baseline for lift-off loads which supported my earlier findings. In February 1987, *Aviation Week & Space Technology* reported that NASA "have recently discovered" negative margins, excessive lift-off loads and other flaws, specifically contained in my reports, six months earlier. I was about to stop my study of the accident, as recognition of shortcomings was made and further necessary corrections were underway.

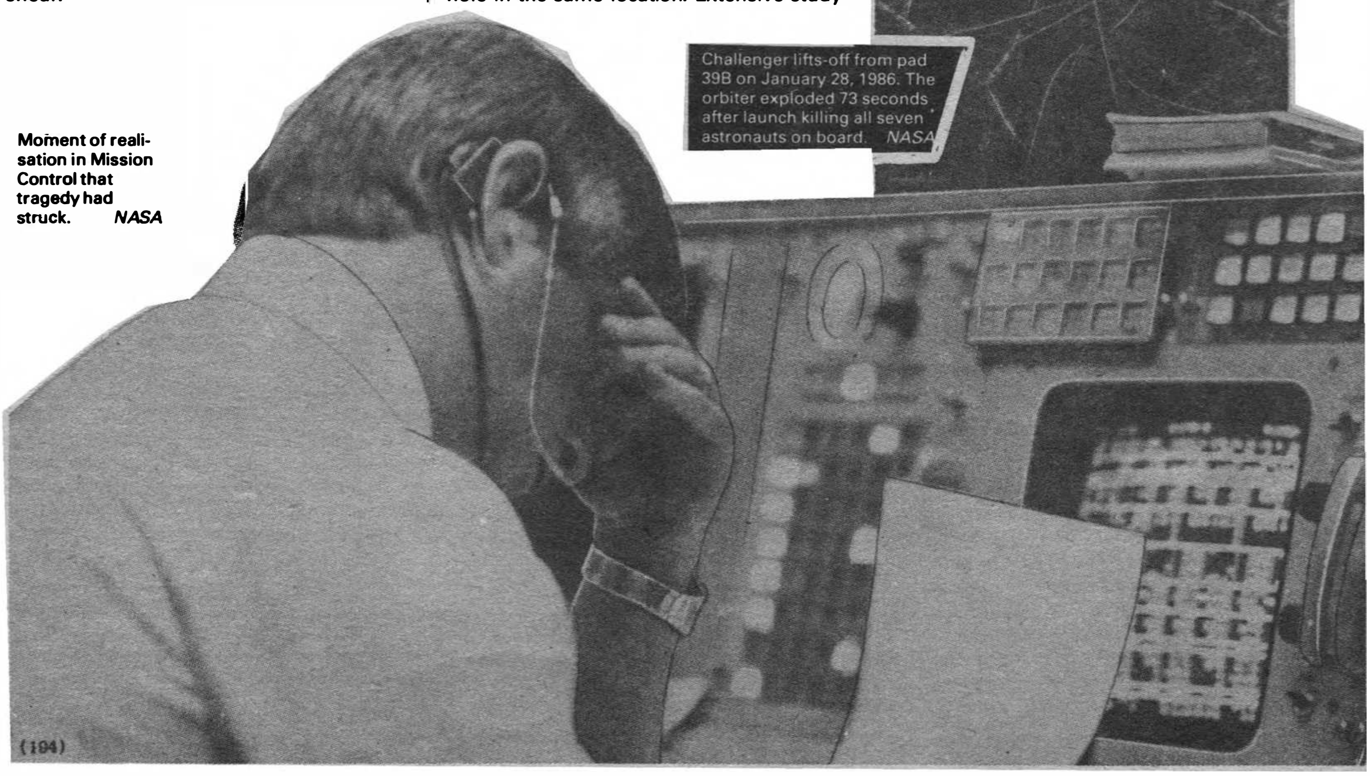
By now, however, I began to discover that the sequence of events from lift-off was grossly in error. The official sequence consisted of detecting black smoke from the aft joint of the right solid rocket booster about half a second after lift-off and the smoke disappeared within three seconds. A flicker of flame appeared in the same area at about 59 seconds, grew in intensity and culminated with the disastrous explosion. The black smoke, the investigators determined, vanished because the leaking joint resealed and the flight then proceeded normally for nearly a minute, affected only by wind shear.

While the black smoke contrasted against the bright background and was easy to perceive, I discovered that leaking hot gases from the booster blended in the intense luminosity of the plumes and the brightness of the day. By simply filtering the glow effect, the raging fire became cearly visible. In flight, the leaking hot gases surged at a fast rate and the mechanics of perception did not allow us to discriminate the fast-paced events.

Slow-motion close-ups and replays revealed the continuous leak which sent out jets of hot gases from an unruly and undesigned nozzle in the side of the booster throughout the flight of the Challenger. The jets struck the external tank and the delicate right wing of the orbiter immediately after lift-off.

Photo 1 shows the officially reported black smoke to the right of the booster, and the firey leak under the wing and a flare penetrating the hinge line of the wing. The recovered wreckage of that wing showed a hole in the same location. Extensive study

Moment of realisation in Mission Control that tragedy had struck. *NASA*



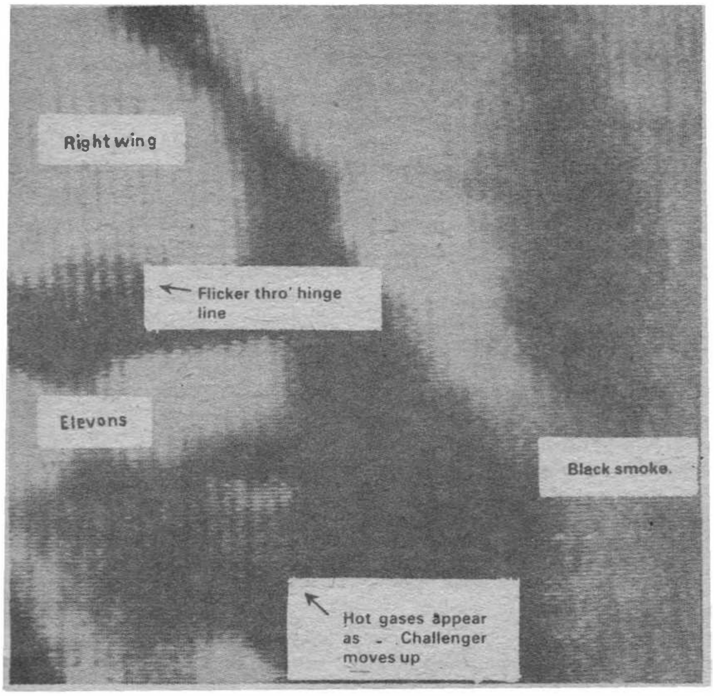


Photo 1. Black smoke to the right of the booster, a fiery leak under the wing and a flare penetrating the wing hinge line *A.F. AbuTaha*

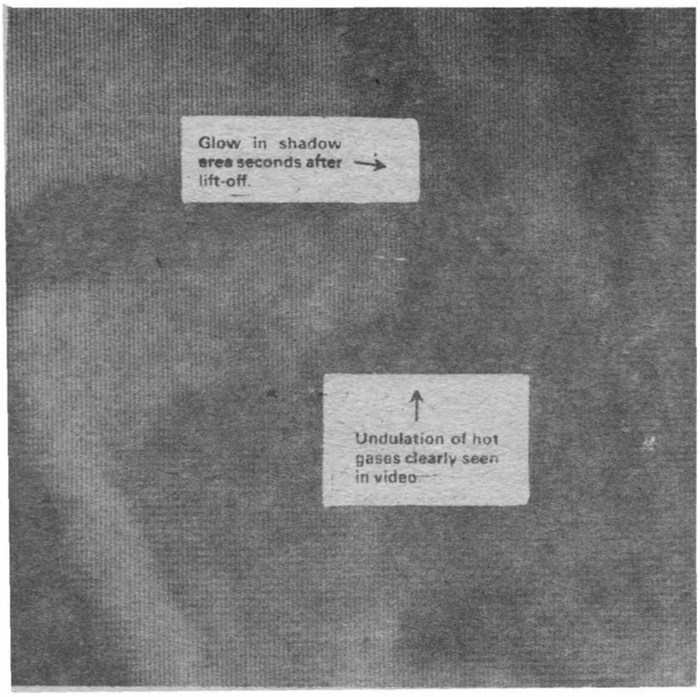


Photo 2 Bright spot immediately to the right of the wing *A.F. AbuTaha*

of this and other camera views eliminated any possibility of error. For example, notice the bright spot immediately to the right of the wing in Photo 2. In the shadow area cast by the wing sunlight cannot cause reflection and geometry precludes reflection from the bright plumes. In video the flickers in the shadow area correlated with the appearance of fire under or through the wing.

But why pursue the tragedy with such fervour? "Conservative" design is not sufficient to avoid disasters. The Titanic did not sink because of inferior design or defective materials, welds or joints. The Titanic sank because an iceberg lurked for it in the dark, and we must identify such dangers in the operation of our spaceships, planes, trains, cars and other engineering systems.

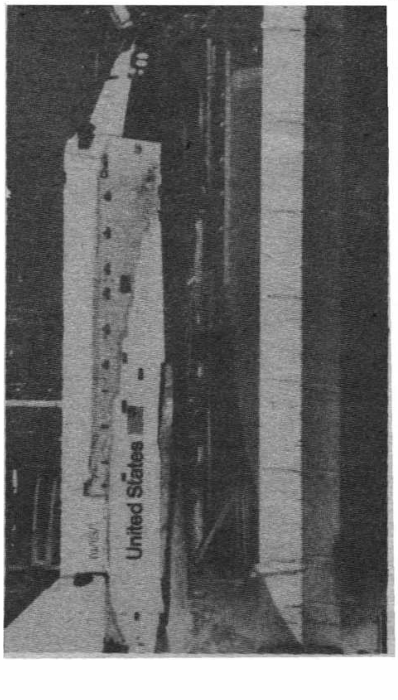
The flight of the Challenger was erratic and was described by a senior NASA official as "fishtailing." The silent plume trail left a zig-zag pattern in the sky and there were other signs of unsteady flight. This was attributed to wind even though reports on the day of the accident indicated "moderate to non-existent" wind. The continuous leak discovery provides a more likely scenario. The Challenger proceeded in a planned trajectory. Flow from the unruly nozzle attempted to divert the assembly from that trajectory. The onboard computers reacted by swivelling the nozzles to return the Challenger to the pre-planned path. Massive forces were thus pitted against each other and accelerated structural break-up.

Nearly two years after the tragedy, the nozzle's outer boot ring failed during the test of a booster (***Spaceflight***, February 88, p.83). The failure was triggered by maximum swivel of the booster's nozzle. "The maximum slewing capability would be used during flight only in contingencies" reported *Aviation Week* on January 4, 1988. This is an ominous sign because maximum slewing of the nozzles should be avoided even in contingencies, and planned trajectories waived if it delays structural break-down, giving the astronauts a chance for survival.

Unwittingly, the investigators, with the tacit approval of the scientific, engineering and oversight groups introduced a fictitious, yet dangerous, window of vulnerability.

The "probability" of joint distress, they said, "is increased to almost a certainty if the temperature of the joint is less than 65 degrees F". Are we then to understand that rockets, with single O-ring joints, carrying warheads will veer off course or disintegrate instantly when launched below 65, 32, 0, or any other temperature?

Black smoke from the lower section of the right booster as Challenger's boosters ignite. *NASA*



My study has shown that the joint failed in flight, about eight seconds after lift-off, and was thus a consequence of another failure in the vicinity of the joint. The "window of vulnerability" must therefore be dismissed lest it may linger in the minds or subconscious of some present or future leaders and engineers and lead to accidental disasters. I might add here that many more Titan rockets than Shuttle rockets have been flown and none of these failed through the less conservatively designed joints (1 instead of 2 or 3 O-rings). My point is self-evident.

The conclusion of the official investigation was an indictment of the common sense of the people who were directly involved in the decision to launch the Challenger. But, since these people are like the rest of us, then the indictment is of the collective common sense in the Country; and this is absurd.

The Challenger tragedy was the result of specific technical mistakes and not the result of indigenous deficiency. Space experts, editors, reporters, supporters and even NASA have lamented the predicament of the space programme in the aftermath of the tragedy rather than accentuated the otherwise excellent achievements of the last quarter century.

In the long run, it is far better for morale and confidence to know that we made mistakes, than to think we were stupid. NASA and the space community should try to convince the US Congress to be giving more to add solid blocks to a sound foundation, rather than appeal, successfully so far, for funds to patch and bandage a "conjured", corroded infrastructure.

The same is true elsewhere, and the British Interplanetary Society's emphasis for urgent and positive action in the recent report by the House of Lords is an admirable example.

ALI F. ABUTAHA

New Mixed Fleet Manifest

NASA has issued an updated mixed fleet manifest reflecting current planning for primary payloads for Space Shuttle missions (full details in chart opposite) and expendable launch vehicles (ELVs) until 1993. The planned next Shuttle launch (STS-26) remains in August 1988.

In addition to supporting Department of Defense mission requirements and the Commercial Space Initiative recently announced in conjunction with the new National Space policy, the mixed fleet manifest continues to reflect the high priority assigned to civil space science and application payloads, both on the Shuttle and ELVs.

A decision to interchange the STS-29 and STS-28 missions eases the orbiter processing flow and enables NASA to maintain the required launch windows for two interplanetary missions in 1989 – Magellan, a mission to map the planet Venus in April, and Galileo, a cooperative project with Germany to survey Jupiter and its moons, in October. The Hubble Space Telescope also maintains its flight assignment date of June 1989.

Astro-1, a Spacelab mission designed to study the universe in the ultraviolet spectrum is being reconfigured to enhance the study of Supernova 1987A, an event that has drawn the attention of astrophysicists from around the world. The Broad-Band X-Ray Telescope has been added to complement the Astro-1 mission now slated to fly on STS-35 in November 1989.

Taking advantage of the recently announced Shuttle landing weight additional capability (***Spaceflight***, January 1988, p.13), Spacelab missions are now planned to fly aboard the orbiter Columbia, which was not previously possible.

Two Spacelab payloads have been assigned flights in 1990 – a Spacelab Life Sciences mission in March and the first of the Atmospheric Laboratory for Applications and Science mission series, ATLAS-1, scheduled for September.

The Gamma Ray Observatory, moved forward in the projected schedule, is now slated for March 1990 and the Ulysses mission to study the Sun and its environment remains in its projected October 1990 launch date.

Another important addition to the manifest is a mission to retrieve the Long Duration Exposure Facility (LDEF) in July 1989. Launched by the Shuttle in April 1984, LDEF was originally scheduled for retrieval in March 1985. The LDEF retrieval mission will replace Astro-1 as the payload for STS-32.

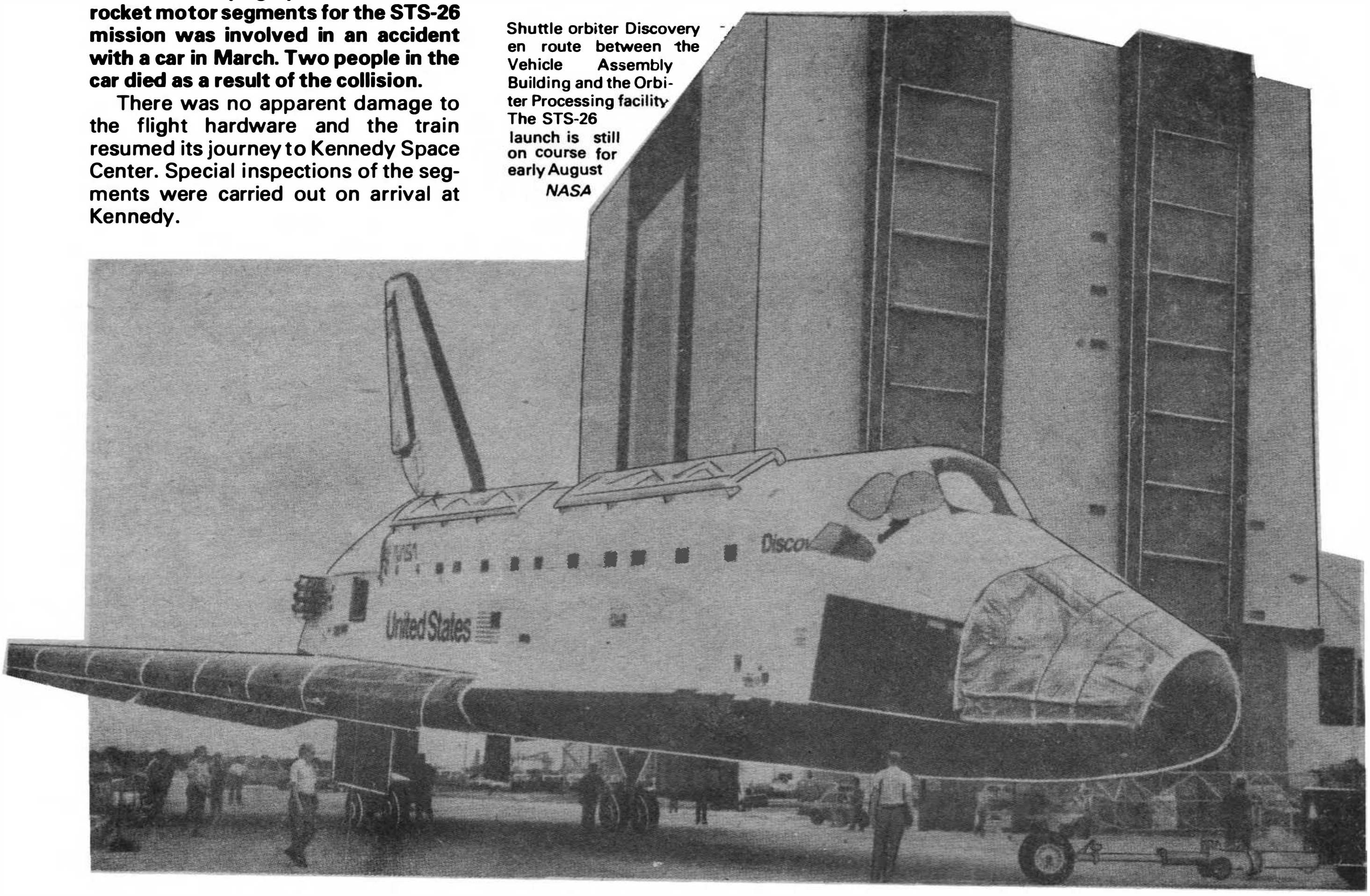
A payload originally planned to have been launched by the Shuttle but now assigned to an unmanned rocket will be the Cosmic Background Explorer (COBE), an Earth-orbiting satellite designed to map the pattern of emissions remaining as evidence of the Big Bang.

As such, this mixed fleet manifest continues to reflect NASA's plans to use ELVs for those payloads that do not need the capabilities of the Space Shuttle. Thirty-five ELV launches are planned by 1993.

Train Carrying SRM Segments in Collision

A train carrying Space Shuttle solid rocket motor segments for the STS-26 mission was involved in an accident with a car in March. Two people in the car died as a result of the collision.

There was no apparent damage to the flight hardware and the train resumed its journey to Kennedy Space Center. Special inspections of the segments were carried out on arrival at Kennedy.



Shuttle orbiter Discovery en route between the Vehicle Assembly Building and the Orbiter Processing facility. The STS-26 launch is still on course for early August
NASA

...NEW... NEW... NE

UP-DATE USA

Space Shuttle Manifest

1988

STS-26, August 4, 1988: The Shuttle Discovery will launch the Tracking and Data Relay Satellite, TDRS-C. A crew of five will have a four day mission.
STS-27, October 10, 1988: Atlantis will be launched on a Defense Department mission. The crew will total five.

1989

STS-29, January 19, 1989: Discovery will carry the Space Station Advanced Radiator Element test payload (SHARE), the Shuttle Solar Backscatter Ultraviolet payload (SSBUV), and will launch the TDRS-D data satellite. This mission had been scheduled as the fourth re-flight; hence the STS-29 and STS-28 numbering reversal. This will be a crew of five on a four day flight.
STS-28, March 2, 1989: Columbia will carry a Defense Department payload. The crew will total five.
STS-30, April 27, 1989: Atlantis will launch the Venus radar mapping interplanetary spacecraft Magellan on its voyage. The crew will total five and the mission will be four days.
STS-31, June 1, 1989: Discovery will launch the Hubble Space Telescope satellite during a five day mission with a crew of five.
STS-32, July 13, 1989: Columbia will deploy the Syncom IV-5 communications satellite and will retrieve the Long Duration Exposure Facility (LDEF) satellite which had been deployed by the Challenger in April of 1984 during the 41C mission. The crew will be five and the mission will be five days.
STS-33, August 24, 1989: Atlantis will carry a Defense Department payload.
STS-34, October 8, 1989: Discovery will launch the Galileo spacecraft on its interplanetary voyage to Jupiter, during a four day mission with a crew of five.
STS-35, November 16, 1989: Columbia will carry the ASTRO-1 ultraviolet astronomical payload and the Broad-Band X-Ray Telescope (BBXRT). The mission will be nine days long with a crew of seven.
STS-36, December 14, 1989: Atlantis will carry a Defense Department payload.

1990

STS-37, February 1, 1990: Discovery is scheduled to carry CIRRIS, Teal Ruby, and Infrared Background Signature Survey (IBSS) payloads on a seven day mission with a crew of seven.
STS-38, March 5, 1990: Columbia will carry the first of the Spacelab Life Sciences missions, SLS-1. The crew will be seven and the duration is not yet determined.
STS-39, March 29, 1990: Atlantis will deploy the Gamma Ray Observatory (GRO) spacecraft during a four day flight with a crew of five.
STS-40, May 10, 1990: Discovery will carry a Defense Department payload.
STS-41, June 7, 1990: Columbia will carry the STARLAB payload of the Spacelab series during a seven day flight with a crew of seven
STS-42, July 19, 1990: Atlantis will launch the TDRS-E data relay satellite, which provides three active TDRS satellites and one on-orbit spare. The crew will be five and the duration will be four days.
STS-43, September 10, 1990: Columbia will carry the first of the Atmosphere Laboratory for Applications and Science missions, ATLAS-1. The ATLAS series replaces the old Earth Observation Mission (EOM) series of payloads. The mission will be nine days with a crew of seven.
STS-44, October 5, 1990: Discovery will launch the Ulysses on its voyage out of the Solar System ecliptic plane and over both polar regions of the Sun during a four day mission with a crew of five.
STS-45, November 11, 1990: Atlantis will carry a Defence Department payload.

1991

STS-46, January 17, 1991: Discovery will carry the initial Tethered Satellite System, TSS-1 and will deploy the EURECA-1 and the first Global Positioning System satellite, GPS-1. The EURECA-1 will perform microgravity experiments in orbit and be retrieved on STS-51. The flight will be seven days with a crew of seven.
STS-47, February 7, 1991: Columbia will carry the first of the International Microgravity Laboratories, IML-1. The mission will be nine days long with a crew of seven.
STS-48, March 14, 1991: Atlantis will carry a Defense Department payload.
STS-49, April 18, 1991: Discovery will deploy the GPS-2 positioning satellite and the Skynet 4A communications satellites, and will carry the Wide Angle Michelson Doppler Imaging Interferometer (WAMDII) scientific payload during a seven day mission. The crew will be five.
STS-50, May 9, 1991: Columbia will carry the Japanese-American Spacelab mission, Spacelab-J during a seven day mission with a crew of seven.
STS-51, June 10, 1991: Atlantis will deploy the Laser Geodynamic Satellite, LAGEOS-2, retrieve the EURECA-1 satellite and it will carry the first commercial middeck extension payload, Spacehab-1. The flight will be seven days with a crew of five.
STS-52, August 8, 1991: Columbia will carry the first Shuttle Radar Laboratory payload, SRL-1. The flight will last nine days with a crew of seven.
STS-53, September 12, 1991: Atlantis will carry the ASTRO-2 astronomical payload and deploy the first International Maritime Satellite, Inmarsat-1 during a seven day flight with a crew of seven.
STS-54, October 31, 1991: Discovery will deploy the Upper Atmosphere Research Satellite (UARS). The mission will be five days with a crew of five.
STS-55, December 19, 1991: Columbia will carry the second German-American Spacelab mission, SL-D2 during a nine day flight with a crew of seven.

1992

STS-56, January 23, 1992: The as yet unnamed replacement Shuttle, OV-105, will carry the Shuttle High Energy Astrophysics Laboratory (SHEAL-2; SHEAL-1 was cancelled) and deploy the first of the Geostar series satellites, GEOSTAR-1. The crew will be five and the mission will be seven days.
STS-57, February 13, 1992: Discovery will carry a Defense Department payload.
STS-58, March 26, 1992: Columbia will carry the first United States Microgravity Laboratory, USML-1 during a nine day flight with a crew of seven.
STS-59, April 16, 1992: Atlantis will carry a Defense Department payload.
STS-60, May 21, 1992: Discovery will carry the PUR-1 payload. The crew will total five and the flight is seven days long.
STS-61, June 11, 1992: OV-105 will carry the ATLAS-2 and deploy a Satcom communications satellite. The flight is seven days long with a crew of seven.
STS-62, July 23, 1992: Atlantis will deploy the first Industrial Space Facility Module, ISF-1. The crew will total five and the mission is five days long.
STS-63, August 24, 1992: Columbia will carry the second Life Sciences Spacelab, SLS-2. The crew will total seven and the mission length is undetermined.
STS-64, September 14, 1992: This Discovery mission is reserved for a possible TDRS/Mars Observer flight. A four day flight with a crew of five is planned.
STS-65, October 15, 1992: The OV-105 will carry the second of the Spacehab payloads, Spacehab-2, and deploy the second Geostar satellite, Geostar-2. The mission is seven days and the crew will be five.
STS-66, November 26, 1992: Atlantis is scheduled for a maintenance revisit of the Hubble Space Telescope during a five day flight with a crew of five.
STS-67, December 17, 1992: Columbia will carry the second Shuttle Radar Laboratory, SRL-2. The nine day mission will have a crew of five.

1993

STS-68, January 14, 1993: Discovery will attach the second Industrial Space Facility, ISF-2 to the orbiting ISF-1, and will deploy the second of the EURECA series, EURECA-2. A crew of five will have a seven day mission.
STS-69, February 25, 1993: OV-105 will carry the first Gravity Probe payload, GP-B1, and will deploy the Inmarsat-2 and Skynet-4B satellites. The mission will be seven days with a crew of five.
STS-70, March 18, 1993: Atlantis will carry a Defense Department payload.
STS-71, April 15, 1993: Discovery will carry the first Orbital Manoeuvring Vehicle mission, OMV-1. The flight will be five days with a crew of five.
STS-72, May 13, 1993: Columbia will carry the second of the International Microgravity Laboratory series, IML-2 during a nine day mission with a crew of seven.
STS-73, June 10, 1993: OV-105 will deploy the GEOSTAR-3 and retrieve the Space Flyer Unit (SFU); a Japanese scientific payload which will be launched on an expendable Delta series rocket. The crew will be five and the mission will be five days long.
STS-74, July 5, 1993: Atlantis will retrieve the EURECA-2 which had been deployed on STS-68. The seven day flight will have a crew of five.
STS-75, July 29, 1993: Discovery will carry the Aero Assist Flight Experiment (AAFE) which will test Aerobraking concepts, and will carry the Spacehab-3 middeck extension. The mission will be seven days with a crew of five.
STS-76, August 19, 1993: Columbia will carry the second United States Microgravity Laboratory, USML-2. The nine day mission will have a crew of seven.
STS-77, September 10, 1993: OV-105 will carry a Defense Department payload.

The above list of payloads includes only "primary" payloads beyond STS-29 Smaller "secondary" payloads such as Spartan, Material Science Laboratories, or Hitchhiker series payloads may be manifested later on a space-available basis. Middeck and GAS cannister payloads would not be manifested until much closer to an individual mission's launch date.

Roelof. L. Shuiling

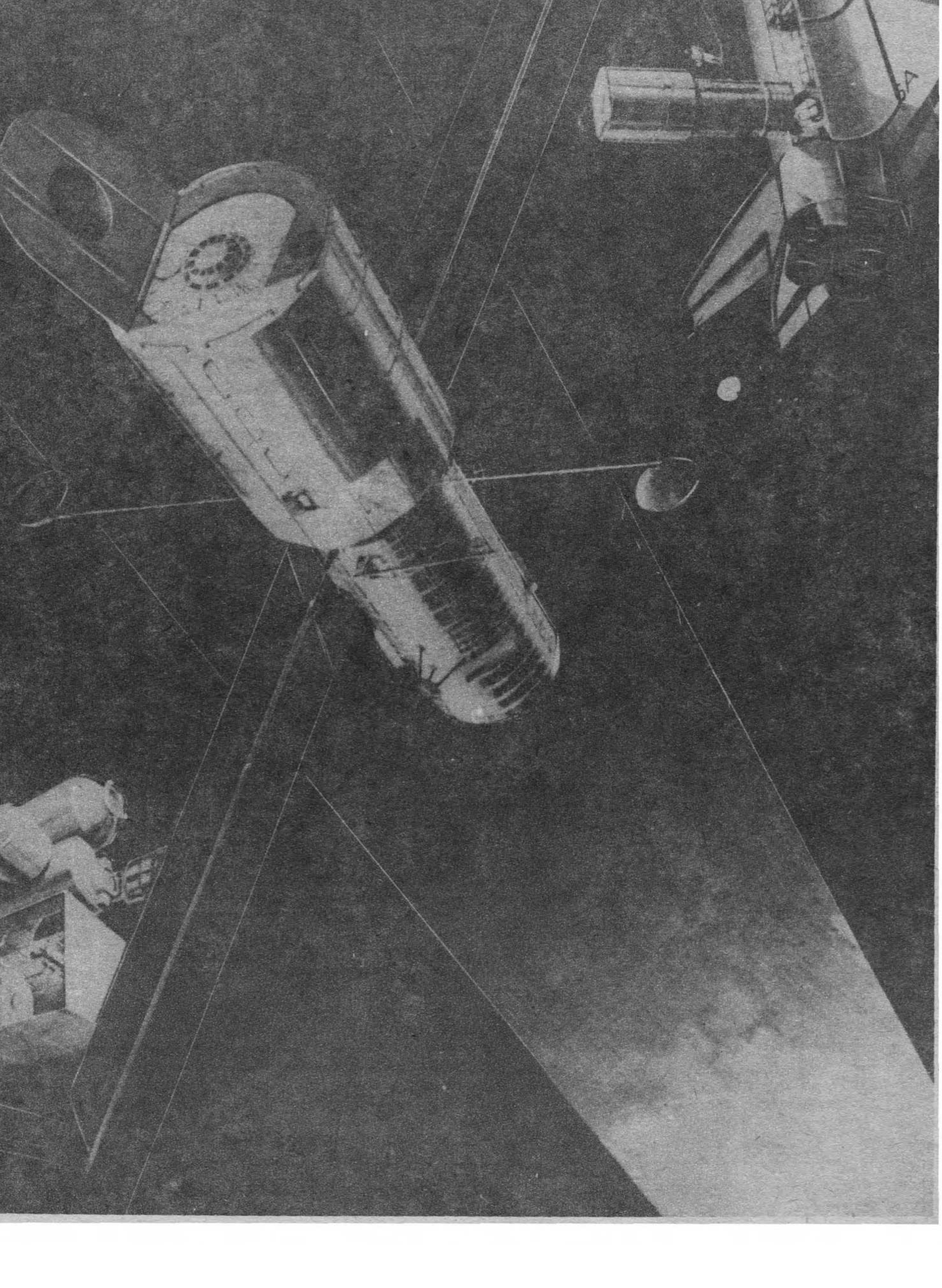
Bid to Build New Telescope

Lockheed is competing for a contract to design and develop NASA's X-ray Astrophysics facility (AXAF) depicted in this artist's concept.

Scheduled to be placed on orbit in the mid-1990's, AXAF will probe the X-ray portion of the electromagnetic spectrum.

Data gathered is expected to unravel some of the mystery surrounding such phenomena as quasars, neutron stars and black holes and scientists hope to learn more about the physical processes that govern our universe.

Like the Lockheed-built Hubble Space Telescope, AXAF will be designed for on-orbit servicing from the space station, as depicted at lower left, or from the space shuttle, as shown at upper right. It is expected to operate in space at least 15 years.



Shuttle Crew Escape Pole

Navy parachutists made nearly 60 successful jumps using a prototype Space Shuttle crew escape pole during recent tests over Edwards Air Force Base, California.

There were a total of 16 tests with six Navy parachutists jumping from a C-141 aircraft travelling at Shuttle air speeds and an altitude of 10,000 feet.

Objectives of the tests were to establish the feasibility of the pole concept for crew egresss and to determine the margins on Orbiter wing clearance.

The telescoping pole is one of two escape systems being evaluated – the other is a tractor rocket extraction system.

For the tests, a fixed curved pole was extended through a hatch-like opening in the C-141. Tests were conducted using both a nine and a 12 foot steel pole extension to determine whether the longer pole provides more clearance.

The pole comes equipped with low-friction lanyards and the jumpers attach a lanyard to their parachute harness and jump from the vehicle, sliding down and dropping off the end of the pole. After about five seconds, the parachute automatically opens and the parachutist floats to the drop zone.

Tests began at airspeeds of 130 knots and graduated to Shuttle air speeds of 200 knots. Instrumentation and photographic data are being evaluated before recommendations are made to Shuttle programme managers.

The escape methods are limited to use during a contingency abort situation or possibly a re-entry landing emergency. If two or three Shuttle main engines were lost during ascent, the crew would bring the vehicle to a controlled gliding flight after seperation from the solid rocket boosters and the external tank. When the orbiter reached 25,000 feet, a crew member would vent the crew module to ensure that no pressure differential existed prior to hatch jettison. The side hatch would then be pyrotechnically jettisoned at approximately 22,000 feet, and crew escape would begin. A crew of eight could nominally egress in less than two minutes.

The telescoping pole was designed and manufactured at Johnson Space Center.

Go-head for Remote Sensing Satellite

The US Department of Commerce and the Earth Observation Satellite Company (EOSAT) here signed a contract to continue the Landsat Earth remote sensing satellite programme into the 1990's.

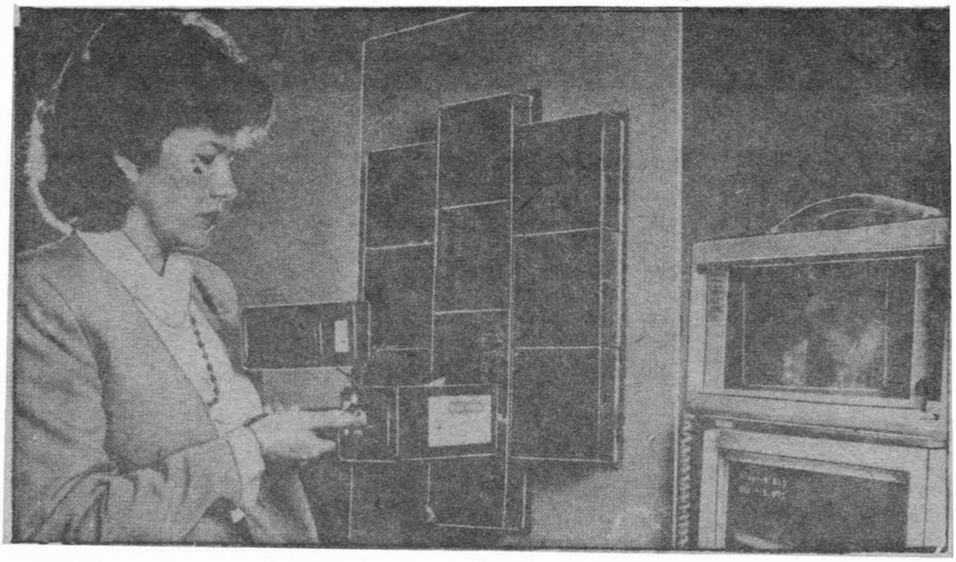
The $220 million agreement provides for the commercial development and construction of Landsat 6 and related ground systems. In addition, EOSAT will continue worldwide market development for Landsat products, and the operation of Landsats 4 and 5.

The Landsat 6 spacecraft will be an Advanced TIROS-N design for launch aboard a Titan II ELV from Vandenberg Air Force Base, California in June 1991.

Landsat 6 will carry an Enhanced Thematic Mapper (ETM) sensor which will provide imaging capability in seven spectral bands with 30 m ground resolution and a 15 m panchromatic capability.

In addition, EOSAT and NASA have developed a Sea-Wide Field Sensor (Sea-WiFS) to provide wide area, low resolution (1 km) ocean colour and temperature information. EOSAT is also investigating the addition of a 5 m resolution, full colour Satellite Tracking and Reporting sensor (STAR).

Rebecca Welling, Lockheed programme manager, demonstrates a two-pound, hand-held prototype instrument that will improve the capability for workers to check the condition of external heat-shield tiles installed on the Space Shuttle. The instrument beams a tiny laser onto the tiles to measure the gap and the surface match of each tile to its neighbour. *Lockheed*



New Abort Landing Sites Readied in Africa

Preparations are under way to bring on line two new Space Shuttle abort landing sites in north-western Africa.

These sites will be used as contingency landing facilities in the event of a transatlantic abort during the launch of STS-26 and subsequent missions.

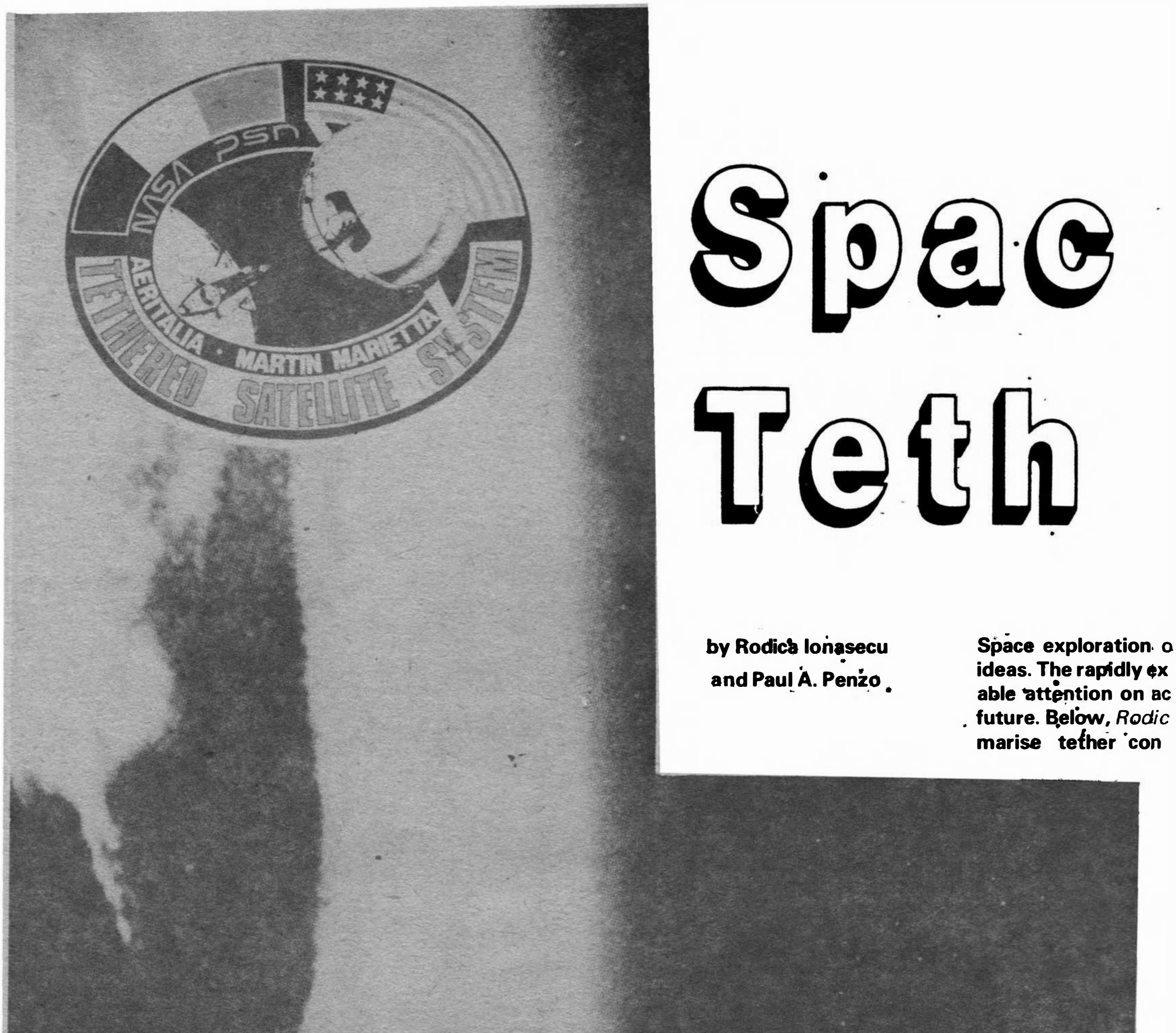
The new sites are located near Ben Guerir (40 miles north of Marrakech), Morocco and Banjul, The Gambia. Ben Guerir, a former US Strategic Air Command base abandoned in 1963, has a 14,000-foot runway. Banjul, with an 11,800-foot runway, currently serves The Gambia as its international airport.

At Ben Guerir, construction to rejuvenate the surface of the runway has begun. In addition, foundations for Shuttle approach and landing aids are being laid at both new sites.

Kennedy Space Center is preparing to ship support equipment to the new locations. Each will recieve about 10 personnel transportation vehicles, a microwave landing system, four sets of Position Approach Path Indicator (PAPI) lights, two sets of Ball/Bar lights, two sets of flashing strobe lights, generators for power, portable satellite communications systems, automated weather stations and other support equipment and tools. Ben Guerir will receive additional fire-fighting equipment.

The total number of transatlantic abort sites comes to four with the addition of these new sites and the continued use of sites at Zaragoza Air Base and Moron Air Base in Spain.

The Ben Guerir, Banjul and Moron sites will be manned with 30 to 40 NASA and contractor personnel during the launch of STS-26.



Spac
Teth

by Rodica Ionasecu
and Paul A. Penzo

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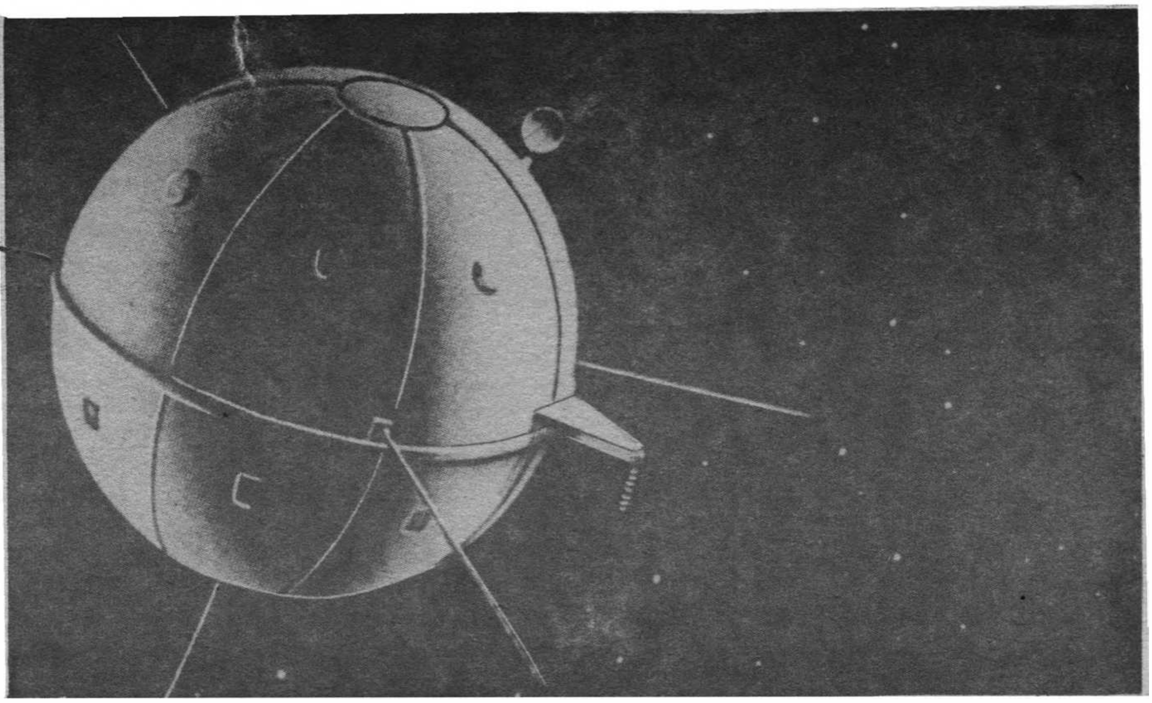

offers many new opportunities . for novel and fascinating
xpanding field of space tethers is now attracting consider-
account of the wide range of applications it promises for the
***ica Ionasecu* and *Paul Penzo* identify this appeal and sum-**
ncepts and current plans. Their more detailed report begins
overleaf.

The concept of tethers in space began in 1895 with Tsiolkovsky's equatorial tower [1]. It was an attempt to reach a weightless environment by simply ascending the tower to a geosynchronous altitude. Obviously, such a tower cannot be built, but some years later, it was proposed to deploy a cable to the surface from geosynchronous altitude [2]. Aside from this novel idea, new concepts for tether applications did not emerge until the late 1960's, and then they were limited to objects connected by long tethers in a gravity gradient orientation, or configurations which would produce artificial gravity [3].

It was not until the early 1970's that more innovative uses for tethers were conceived. It was during that time that Grossi [4] and Colombo [5] suggested the idea of using a conducting tether in the Earth's ionosphere, to generate ELF/ULF waves for communication with Earth. Other ideas emerged quickly. For atmospheric studies, for example, a non-conducting tether could be lowered into the inaccessible regions of the Earth's upper atmosphere. These ideas led to the Shuttle-borne Tethered Satellite System (TSS) which is a joint undertaking between NASA and Italy's National Space Plan (PSN). As the concepts of the electrodynamic tether and the nonconducting tether matured, investigators thought of applications in new areas, for example for transportation and planetary missions. In addition, applications in the areas of science, electrodynamics and controlled gravity in which a few concepts first originated became more extensive.

What makes the use of tethers so appealing to those familiar with them? It is the diverse set of applications which expand the use and flexibility of space. Also appealing is the fact that, with effort, many of these applications may be implemented in the coming decade or two. This requires concentrated technology development on the ground, and tether demonstrations in space.

For example, a tether which connects two masses can provide separation of the masses with ability of deployment and retrieval using a reel system. Among these applications are tethered probes for lower atmospheric studies, docking of transportation vehicles (e.g., shuttle, OMV) to the space station, science platforms removed from disturbances and/or contamination of the space station and, in planetary space, acquisition and return of comet/asteroid samples.

When a tether system orbits a planet such that the tether remains aligned with the local vertical; the end masses experience a gravity gradient force which provides the tension in the tether necessary for stability. The same outcome can also be achieved by spinning the tether. For ease of operations, platforms connected by a tether can be accessed by an elevator riding on the tether. The induced tether tension can be felt at the end masses. This artificial gravity can be varied by either adjusting the tether length or increasing the spin rate, in which case scientific experiments can be performed at the end masses or platforms.

A conducting tether, gravity stabilised along the vertical, and moving across a planet's magnetic field lines, (e.g. Earth, Jupiter) will have an electric potential induced in the wire. Closing the circuit through the ionosphere could provide power. Forcing current through the wire in the opposite direction using a power source could provide thrust on the wire, and hence the attached vehicle (see Fig. 1 overleaf).

In the next decade, a special effort will be made to develop and verify a technology that has emerged from the unique possibilities offered by tethers. The outcome will determine the feasibility of the many applications that have been proposed in the areas of Science, Transportation, Electrodynamics, and Planetary Exploration.

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Tether Technology Has Its Own Special Appeal

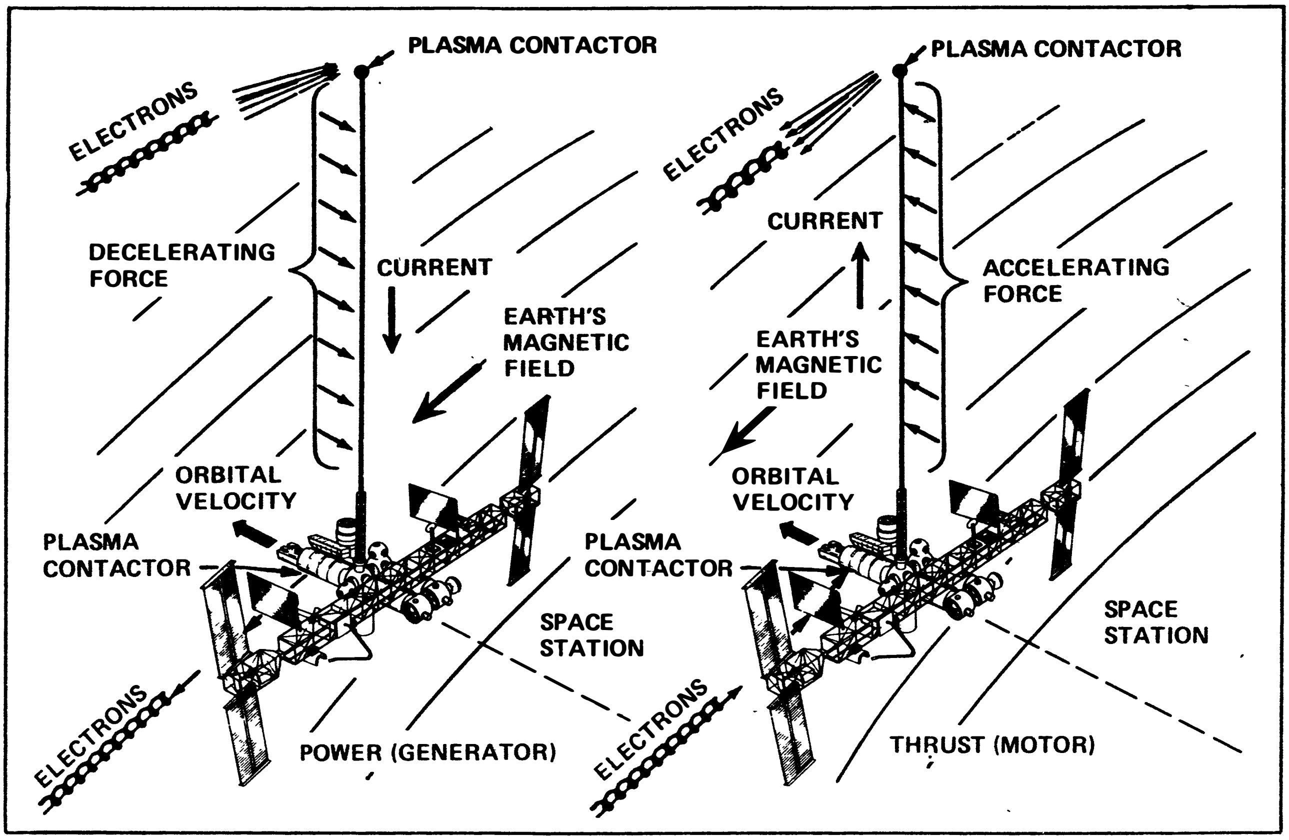


Fig. 1. The principles of power and thrust generation using a conducting tether are illustrated here.

Innovative Uses of Space Tethers

Several demonstrations of the conducting and non-conducting tether behaviour in space have been approved for flight on the US shuttle. Others await further work on the mission design aspect.

The demonstrations proposed for the next decade will verify our understanding of the behaviour of tethers and further applications.

In this article *Rodica Ionasecu* **and** *Paul A. Penzo* **discuss the demonstrations that have already been approved for flight or are in the design stage.**

Planned Demonstrations

The forces responsible for producing tension in a tether are the force of gravity and possible centrifugal and electrodynamic forces [1]. Much work has already been done to understand the dynamics of tethers and tether systems [2].The electromagnetic properties of tethers will be verified in an experiment that represents a milestone in the cooperation between the United States (through NASA) and Italy in tether work. Called the Tethered Satellite System, it will consist of three missions of which only the first one (TSS-1) has been manifested for Shuttle launch.

This first mission [3] will deploy a tethered satellite upward, away from the shuttle on a 20 km insulated conducting wire. The purpose of this mission is to demonstrate that current can be made to flow through a conducting wire travelling across the Earth's magnetic field lines and through the ionosphere, and also that a reactive drag force will be imparted to the wire. In order to have a current in the wire as a result of the potential difference across the tether, the tether ends must make electrical contact with the Earth's plasma environment.

The Electrodynamic Plasma Motor/Generator Proof of Function (PMG/POF) Experiment [4] will determine if hollow cathode plasma sources can couple electric currents from either end of a 200 m wire moving through the ionosphere in low-Earth orbit (LEO). The tether has a hollow cathode at the Orbiter end and a 25 kg Far End Package (FEP) with a hollow cathode system at the other end. The experiment begins with the release of the FEP by the Orbiter and ends when the FEP gets far enough away to cause tension in the wire. The wire and the FEP are then detached from the Orbiter. The PMG/POF missions belong to a special class of experiments which have a low cost deployment and on-orbit opera-

tion since they only require deployment of umbilical wires as opposed to the full range of options of tether deployment, control and retrieval.

The electric currents induced in electromagnetic tether systems can be used as a source of power on board the spacecraft at the expense of spacecraft/tether orbital energy. However, if the direction of the induced current in the wire is reversed by means of an onboard power supply, the force experienced becomes a propulsive one [5].

A propulsive force can also be achieved through momentum exchange. Consider a non-conducting wire connecting a spacecraft to a payload. If the payload is deployed upward from the spacecraft to where the two mass system becomes gravity gradient stabilised, at which time the tether is severed, the upper mass will experience a boost in its orbital energy at the expense of the lower mass, which will be deboosted. The Small Expendable Deployer System (SEDS) experiment will demonstrate the ability of a 20 km disposable tether to boost a payload from the shuttle into a higher orbit without fuel expenditure [6].

Demonstrations Under Design

In addition to conducting important scientific experiments, the TSS-1 mission will only partially demonstrate the electromagnetic properties of a tether, namely, the power generation aspect. A demonstration presently in the design stage called the Get-Away Tether Experiment (GATE) will use tether electrodynamics to provide thrust in addition to power generation. Several scientific experiments will also be performed. The free-flying tether system deployed from a Get-Away Special (GAS) canister will consist of two parts separated by a 1 km conducting tether, a reel mechanism with an electric motor, and batteries [7].

Other scientific experiments await demonstration on the TSS-2 mission, which is currently being designed. A non-conducting 100 km tether will be deployed downward from the Shuttle into the Earth's upper atmosphere where it will take aerothermodynamic measurements (see Fig. 2). At present, this region of the atmosphere has only been accessed with sounding rockets and the shuttle during re-entry, both of which have short flight times which limit their ability to cover a wide area [5,8].

Tethers offer a wide range of possibilities for scientific experiments in space. Aeritalia, under contract with Italy's National Space Plan, has studied two other concepts, namely, the Space Elevator and the Pointing Platform. These applications will be demonstrated on the shuttle prior to their implementation on the space station. The Space Elevator, an element able to move along a tether, will serve as a means for achieving the controlled gravity environment necessary for microgravity experiments and for transportation. In the second concept, the tethered Pointing Platform, the stabilisation and pointing of the platform will be controlled by moving the tether attachment point and relying on the torque produced by the tether tension [9].

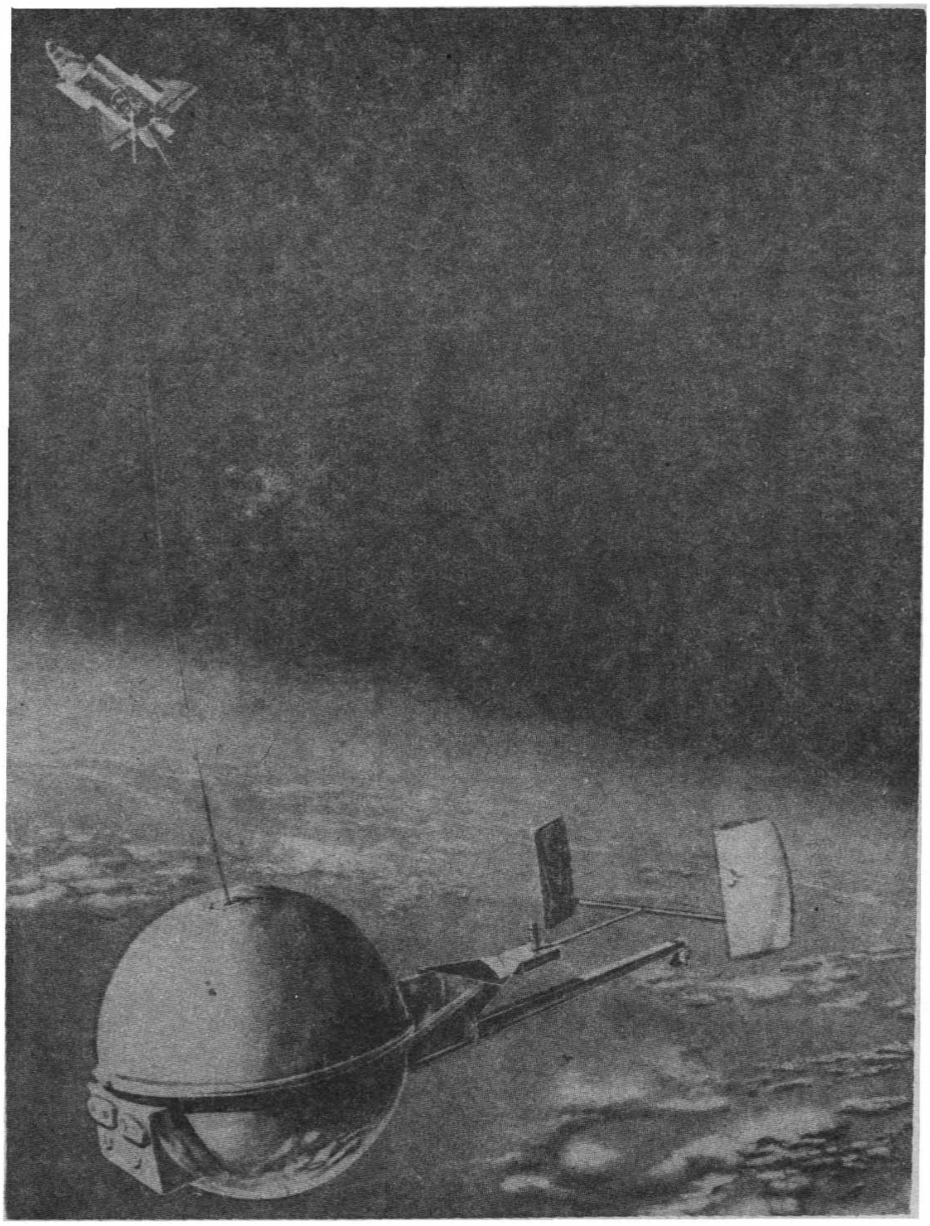


Fig. 2. The second US-Italy tethered satellite mission (TSS-2) will deploy an atmospheric probe downward from the Shuttle on a 100 km tether. The satellite will be towed at a 120 km altitude for a day or two collecting scientific data before being reeled back to the Shuttle for return to Earth.

Another proposed space shuttle flight demonstration, the Kinetic Isolation Tether Experiment (KITE), will show whether providing attitude control and fine pointing to a space platform by moving the attachment point of the tether is feasible [10]. This US experiment will also include a space shuttle rendezvous procedure with the spacecraft SPARTAN 1, which will be modified to carry the actuator and the instrumentation required to demonstrate the tether experiment. As part of the rendezvous procedure, the tether connecting SPARTAN 1 with the shuttle will be severed at both ends [11] before the shuttle recovers the spacecraft.

In one of the approved demonstrations, SEDS, momentum exchange is used to boost the payload. The second SEDS flight is tentatively reserved for deboosting a re-entry vehicle as part of the same concept. This demonstration called the Tether Initiated Recovery System (TIRS) will use a tether to deploy a re-entry vehicle and set it on a suitable trajectory which will allow it to re-enter the atmosphere and be recovered [12].

Once the concepts in the technology demonstrations are verified, greater confidence will be gained in the feasi-

bility of more involved applications. What these applications are and how they will help us explore space in the next 20 years will be discussed in the sections that follow. The sections separate the applications by categories (science, transportation, electrodynamics, and planetary). Only a sample of possible applications will be presented, based on the status of the application and its feasibility as determined from current studies.

Tethers for Science

Undoubtedly tethers hold great promise for future scientific research providing the capability to explore new areas in space and "touch" objects like comets and asteroids which have eluded us ever since their discovery. While the exploration of any of the bodies in the Solar System can be classified under science applications, we will include in this category only applications that can be performed near Earth and group the others under planetary.

The TSS-2 mission in particular will open an era of atmospheric research from the shuttle. Among the applications are simultaneous atmospheric measurements taken with a large number of probes mounted along the tether [5]. Aerothermodynamic measurements of the region down to 125 km and perhaps as low as 90 km in the Earth's atmosphere could be performed with a sub-satellite towed by the shuttle.

Once a shuttle demonstration of the Tethered Elevator and Pointing Platform are completed, the two can be incorporated on the space station. Removed from the contamination and mechanical disturbances of the space station, a pointing platform could be used for Earth and Space observations of short duration. The tether itself could serve multiple functions: transmit data, provide power to the pointing platform and allow a space elevator to vary its level of gravity by changing its position along the tether. As a result, the elevator and an attached module

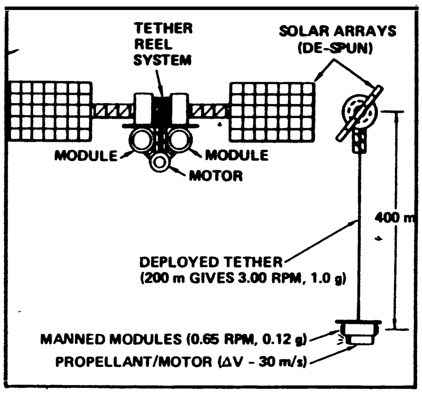


Fig. 3. This rotating system can produce variable gravity in the manned modules by varying tether length. A similar system could be used to provide gravity for an Earth-Mars transfer vehicle.

will present a unique environment for microgravity and controlled gravity experiments.

Other tether applications for science, such as an early version of an artificial gravity rotating platform for the life sciences (see Fig. 3), are too numerous to discuss here in some detail. Table 1 lists those that have been proposed for the major scientific fields.

Tethers for Transportation

As the SEDS and TIRS demonstrations will show, momentum exchange between two bodies connected by a tether can be used beneficially for either boosting the upper body into a higher orbit or deboosting the lower body for re-entry into the atmosphere by disconnecting or severing the tether. This technique could be optimised to minimise propellant consumption necessary by equalising the momentum exchange between the bodies departing the space station to lower orbit, which raise the space station's altitude and bodies departing the space station to higher altitude, which lower the space station's altitude. For example, downward deployment of STS, waste disposal, ET and small payload re-entry could be counterbalanced by the upward deployment of OTVs or the drag on the space station caused by electrodynamic tethers generating power (Fig. 4).

A study conducted by Martin Marietta Denver Aerospace [13] under contract to NASA MSFC has resulted in a method for maintaining the space station at an altitude accessible to the shuttle without propellant expenditure, by taking into account atmospheric drag variations caused by the solar cycle. Since a full cycle will occur between 1994 and 2004, the method suggests using a variable lower altitude for the space station for the whole duration of the solar cycle, which should however, be combined with tethered OTV launches once the OTV becomes available at the end of the 1990s. The potential net cost benefits over the 11 year period range from $1.08B to $2.13B.

The Italian Space Agency (PSN), in cooperation with Aeritalia, has performed studies in which the concept of a Tethered Elevator-based Re-entry Probe (Fig. 5) emerged. This could be used for either atmospheric measurements or transportation of test samples or crew members back to Earth. The elevator-tether combination will permit a fine tuning of the re-entry trajectory and a smoother return of the transport vehicle [14]. This feature is planned as a permanent add-on to the space station based tether deployment system. The alternative to this application would be a simple tethered re-entry system without the elevator [5].

Orbital boost may also be accomplished by capturing energy from the Earth itself. For example, the altitude of a tethered satellite in a circular near-polar orbit around an oblate planet may be raised by means of the resonant interaction between the satellite and the planet [15]. It is only necessary to have the tether itself oriented at a certain angle with the vertical when crossing the equator. Here, release or capture of a mass is not necessary, although the tether has to be quite long. Other transportation applications

Table 1. Scientific applications for tethers.

FIELD	MEASUREMENT	METHOD OF TETHER USE
Aeronomy and Aerodynamics	Neutral Density, Ionosphere Chemical Interactions Fluid Dynamics	Repeated use of Shuttle deployed TSS with appropriate instrumentation, and/or aerodynamic models for wind tunnel simulations. Models may be powered. Instruments may be spaced apart on tether.
Geodynamics and Remote Sensing	Geomagnetic Fields, Earth Gravity Field Crustal Investigation, Cartography Vegetation Analysis, Hydrology	A platform may be tethered downward from the Shuttle or the Space Station to isolate from STS/SS, to provide stereo measurements (SAR), or improve sensitivity of instruments by moving closer to Earth.
Electrodynamics	Ionosphere, Plasma Physics ELF/ULF Propagation	A tethered satellite upward or downward from the Shuttle or Space Station could be instrumented for passive measurements, or active current induced measurements using electron guns or hollow cathodes. Effectiveness of ELF/ULF Alfven wave transmission for communications to Earth could also be investigated.
Physics and Astronomy	Gravitational Constant Improvement Synthetic Aperture Interferometry Gravity Wave Detection	Two sensitive instruments or telescopes may be tethered together and rotated to provide high resolution data or images. Technology development is needed to ensure high pointing accuracy, orientation control, and wave length accuracy distance measurements between them. The tether can provide large separation, accurate control and act as a communication and power line.
Life Sciences	Zero-G Effects on Cells, Humans, Animals and Plants Osteoporosis Experiments, Zero-G Medicine, Long Duration Low Gravity Studies	Zero-G effects on humans, becoming more serious as USSR fails to solve the debilitating effects on humans exposed for many months; and also since manned Mars exploration is contemplated. A rotating tether system is ideal for generating all levels of gravity with large laboratory volume and low Coriolis effects.

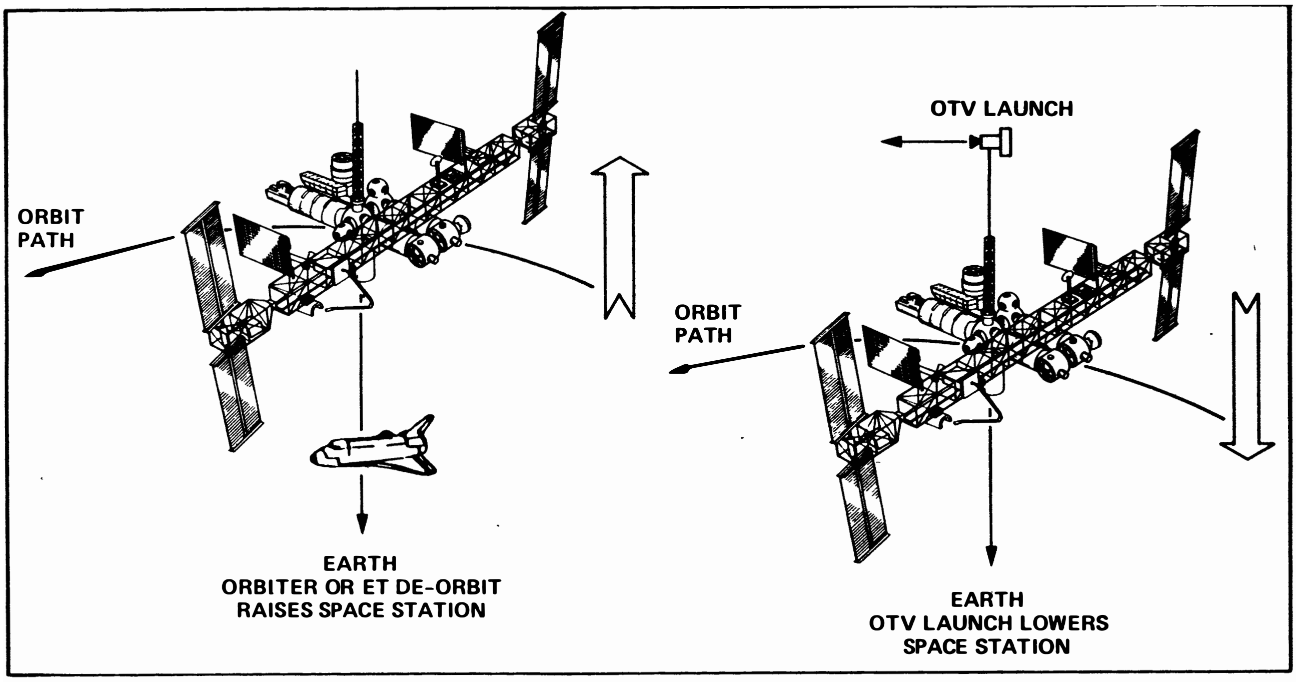


Fig. 4. The Space Station may be used as a momentum transfer facility.

will be described in the planetary section.

Tethers for Electrodynamics

The most rewarding application of tethers to enhance man's use of space may be the electrodynamic tether. If the process could be made practical, it will be possible to extract orbital energy and transform it into power using Earth's magnetic field and ionosphere. What is urgently needed at this time is a greater understanding of the physical process through ground based research and a demonstration mission in space. As discussed in the Planned Demonstration section, the Plasma Motor/Generator Proof of Function (PMG/POF) and the Get-Away Tether Experiment (GATE) will verify the effectiveness of hollow cathodes as plasma contractors for an electrodynamic tether used to generate power and thrust.

The NASA Johnson Spacecraft Center has defined four "PMG Reference Systems" as a basis of comparison in studies of future tether propulsion and power applications [16]. The tether systems here are designed for nominal operation at 2 kW, 200 kW, and 1 MW, and permanent deployment. These systems could be used with solar arrays to either offset drag in LEO, or replace batteries for power storage, and they could provide propulsion for orbital manoeuvres. The power generated by the conducting tether depends, however, on $(V \times B)^2$, where V is the satellite orbital velocity, and B is the magnetic field. Since both parameters decrease with altitude, namely, $B \propto 1/r^3$, and $V \propto 1/\sqrt{r}$, the power falls off with $1/r^7$, and has a zero value for polar orbits [21].

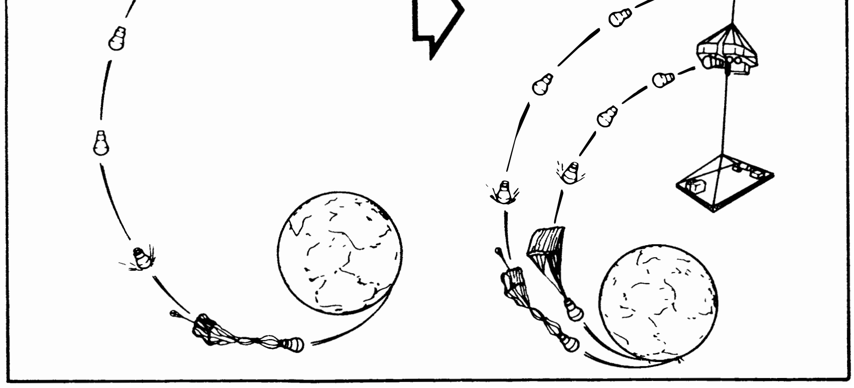
Reference 17 limits the range of applicability of electrodynamic tether systems to altitudes between 500 to 2000 km and inclinations below 60 degrees. The upper limits coincide with 25 per cent effectiveness for a 20 km tether and 25 kW auxiliary power system for the space station. A 100 per cent effectiveness of this system coincides with a 500 km equatorial orbit.

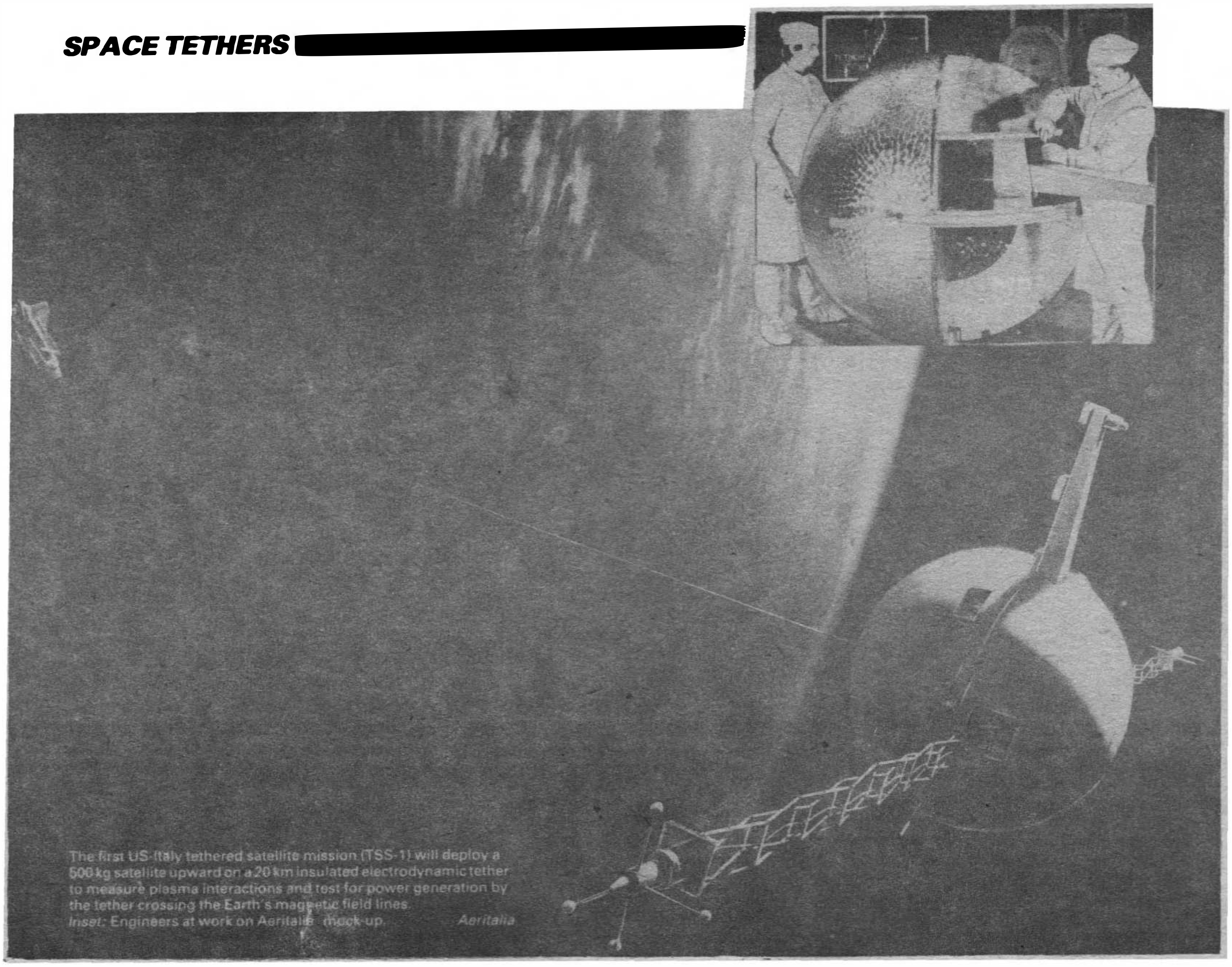
A systems study of a 50 kW, 20 km electrodynamic tether [18] shows daily fluctuations in the open circuit voltage due to a tilted geomagnetic dipole field and in the plasma density due to solar illumination (day vs night) and sun spot activity. Since electrodynamic thrust depends on an integrated electron density, while power generation relies on a constant electron density, the former will be unaffected by electron density fluctuations while the latter will require batteries as a back-up for night time operation (Fig. 6). Thus, only partial battery replacement by a tether is desirable for power generation.

Planetary Tethers

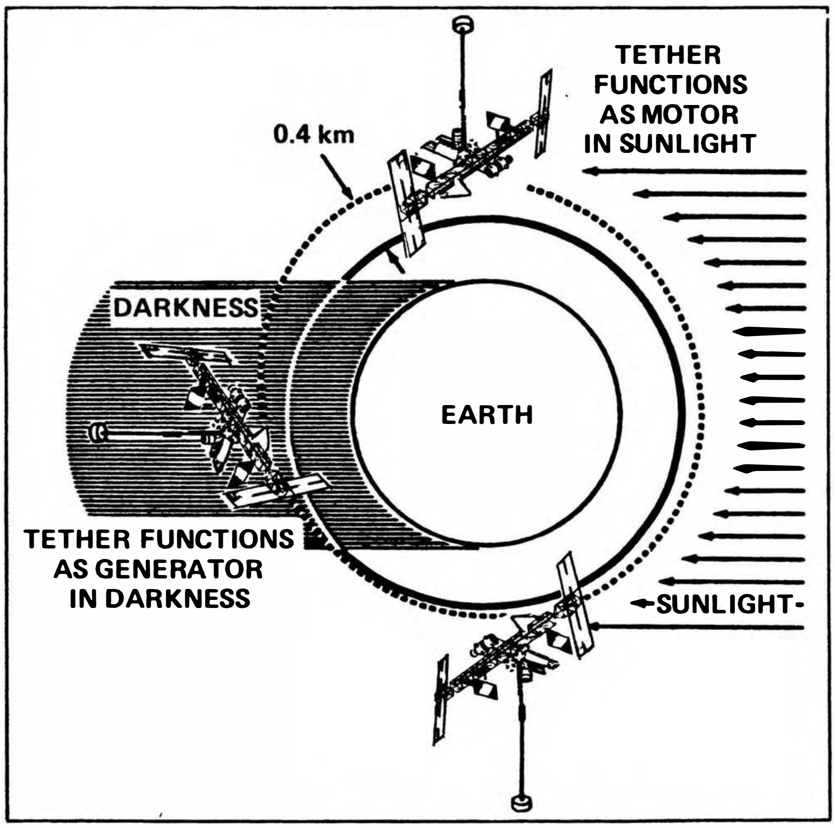
Many of the tether uses discussed above may be applicable to other bodies of the solar system [19]. For example, the Mars Aeronomy Observer (MAO), which is planned for launch in 1994 or 1996, could be equipped with an instrument package

Fig. 5. Italian concept of entry probes released from an elevator crawling along a tether which supports a platform.





The first US-Italy tethered satellite mission (TSS-1) will deploy a 500 kg satellite upward on a 20 km insulated electrodynamic tether to measure plasma interactions and test for power generation by the tether crossing the Earth's magnetic field lines.
Inset: Engineers at work on Aeritalia mock-up. *Aeritalia*



attached to a deployable tether as part of the mission scenario for Martian atmospheric studies (Fig. 7). To avoid excessive drag effects, the package, with instruments for in-situ measurements of the upper atmosphere, could be deployed downward for only a few hours per month, remaining with the spacecraft at the higher altitude most of the time. Actual launch may have to be delayed for this development, but the TSS-2 mission would provide the experience for designing and operating the required deployer system. A similarly equipped spacecraft could be used at Venus, or even Titan.

A tether system could also be of benefit on airless bodies [19]. At the Moon, instruments could be deployed arbitrarily close to the surface for sensing composition and the gravity field. The spacecraft itself could remain at a higher, more stable, orbit. Tether length could be varied to avoid impacting the surface and to compensate for changes in the orbit altitude. This technique could be more applicable to bodies like asteroids which have irregular surfaces.

Transportation applications, using momentum exchange and releasing

Fig. 6. Electrodynamic tether functions as night time power generator for the Space Station.

and capturing vehicles or payloads, are more effective and less demanding of tether strength on smaller bodies [20]. For example, two tethers may be placed on each of the Martian satellites, Phobos and Deimos (one up, one down), to capture masses from low Mars orbit and release them to escape [21]. That is, Phobos, the lower satellite, could capture a suborbital vehicle on the downward hanging tether. The vehicle could then be reeled to Phobos and deployed on the upward hanging tether. Release from a certain distance would cause the vehicle to rise and rendezvous with the downward hanging tether of Deimos. Repeating the reel-in, deploy and release process on Deimos, will result in the vehicle escape from Mars. This process is reversible in going from escape to low Mars orbit and the strength of current materials for tether is sufficient for this application.

Other planetary applications of tethers have been proposed, some requiring tether systems added to current spacecraft designs and others requiring much larger and complex systems. A summary of these applications is presented in Table 2.

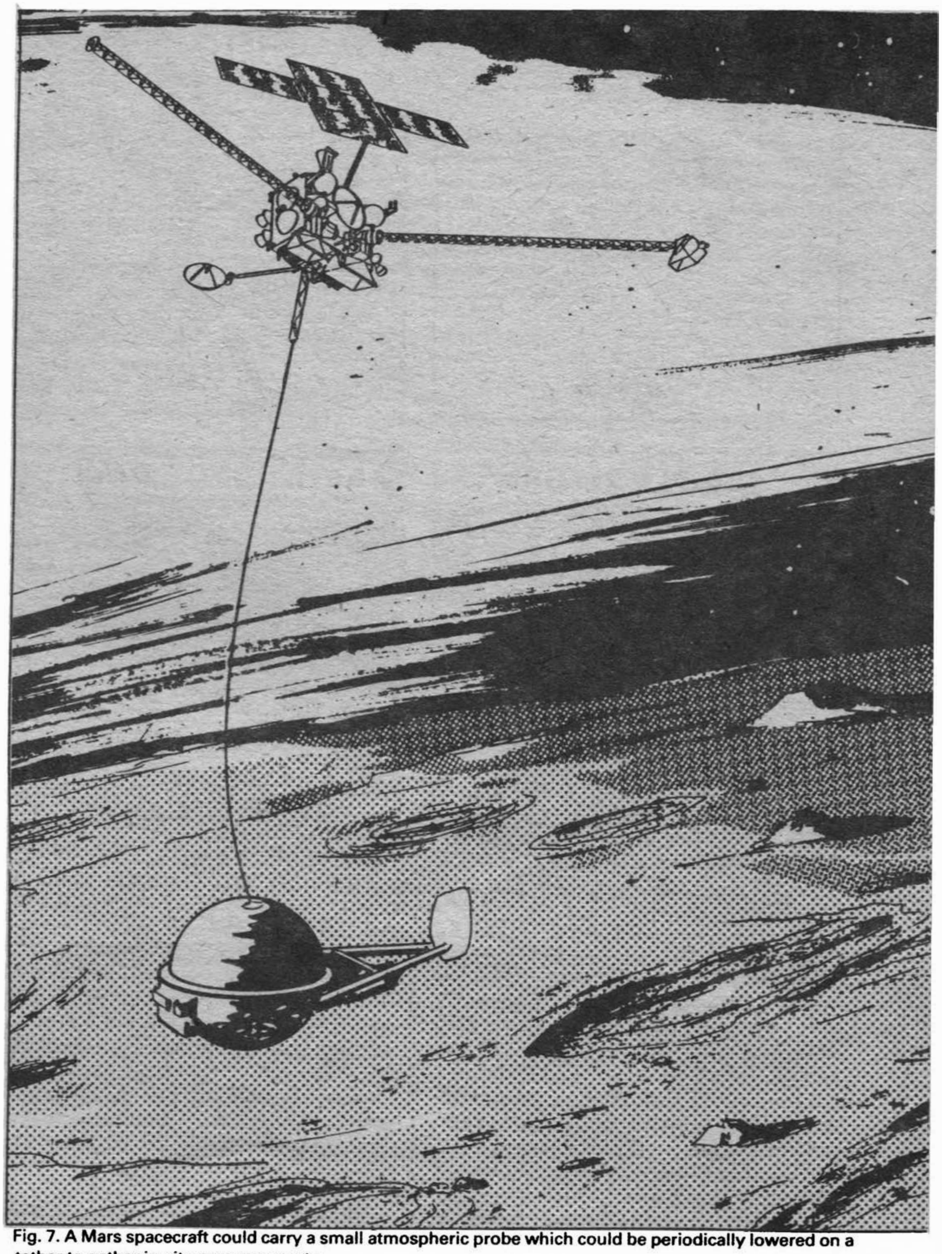


Fig. 7. A Mars spacecraft could carry a small atmospheric probe which could be periodically lowered on a tether to gather in-situ measurements.

Conclusions

It has been possible here to describe the many innovative uses of tethers in space in only the briefest manner. Very likely, these ideas would not have been forthcoming and certainly not taken seriously, were it not for the early efforts of G. Colombo and the initiation of the TSS series of missions. One should not be misled, however. Most of these applications will require considerable technology development and testings and demonstrations in space.

As discussed on p. 201 the experiments that have been proposed will address only some of the pending issues regarding the use of tethers, namely, tether deployment and control

Table 2. Planetary applications for tethers.

BODY	APPLICATION	METHOD OF TETHER USE
Moon	Gravity Field, Composition Mapping	Lower a tethered set of instruments downward close to the surface for more sensitive measurements, from a satellite in a high (200 km), stable, polar orbit.
Mars, Venus, Titan	Neutral Density, Ionosphere Chemical Interactions	Use the TSS capability on a Mars Observer Satellite to get measurements lower in Mars, Venus or Titan atmosphere.
Earth, Moon	Tether Transport System	Place tether stations in LEO and LLO to aid in the transport of material to and from the Moon.
Phobos, Deimos	Tether Transport System	Place tether systems on Phobos and Deimos to aid in transporting vehicles from low Mars orbit to escape, and from Mars hyperbolic approach to low Mars orbit.
Asteroids, Comets	Sample Return	Use a tethered penetrator or drill system ejected from a hovering spacecraft to capture samples from the surface of a small body and return it to the spacecraft.
Earth, Mars	Artificial Gravity Transfer Vehicle	Provide artificial gravity to astronauts during the long flights between Earth and Mars by using a rotating tether system.
Jupiter	Inner Magnetosphere Manoeuvring Vehicle	Use an electrodynamic tether in Jupiter's strong inner magnetosphere to produce drag or thrust to aid a spacecraft manoeuvre in orbit about Jupiter.
Asteroids, Moons	Artificial Gravity Assist	Allow a small body to provide some gravity assist for orbit changes during a flyby, by ejecting a tethered penetrator which will attach to the body and allow the tension in the tether to swing the vehicle into a new orbit. The tether is then detached from the body to complete the manoeuvre.

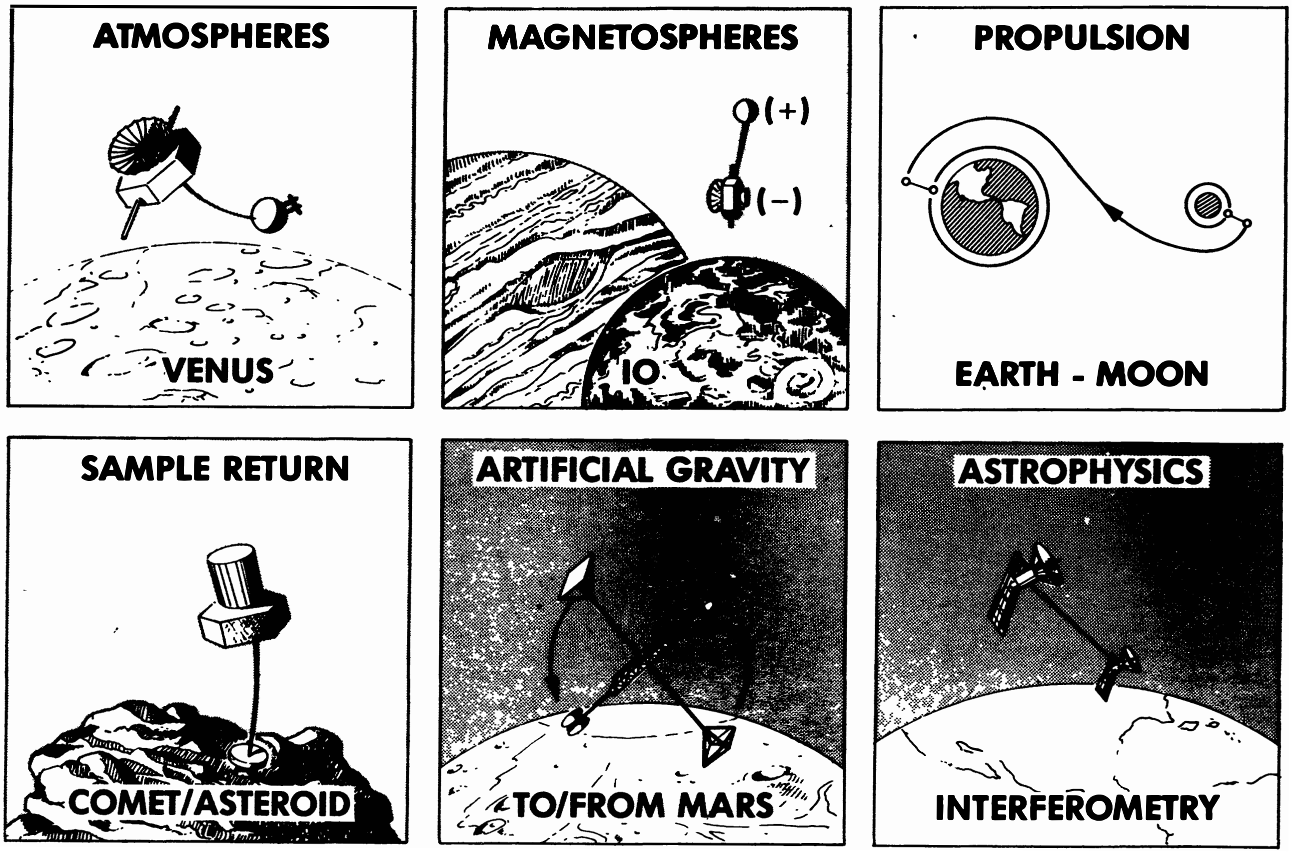


Fig. 8. Summary of the planetary and astrophysical applications which may be possible with the use of tether technology.

laws, recoil, electrodynamic effects, tether strength and survivability in the lower atmosphere, stability of a tethered platform and propulsion through momentum exchange. These issues, however, will be investigated on the shuttle only, and will be limited by the shuttle introduced disturbances and by the shuttle flight time.

Numerous simulations of tether dynamics and control laws have been designed to aid in the understanding of tether behaviour in space. These studies have been primarily directed at shuttle-borne tethered systems, and involved rotational dynamics and deployment vibrations, station keeping and retrieval phases [22].

Several studies performed recently used optimal control theory for retrieval rate histories [23] to reduce in-plane and out-of-plane librational motions of tethered satellites and to stabilise a platform with a massive tethered subsatellite modelled as a three dimensional mathematical model [24]. In addition to these control laws an alternate concept to the tether retrieval problem was proposed by Kane [25] and further studied by Glickman and Rybak [26].

Most applications of tethers presented here are near Earth. It may well be that the more exotic and rewarding applications will be in deep space and other bodies of the solar system; perhaps to detect gravity waves, provide gravity for an Earth-Mars vehicle or aid in collecting samples from asteroids and comets. Whichever applications become important, this survey indicates that there are many to choose from. One prediction that can be made with some confidence is that, at some time in the future, the longest structures in space will have tethers as main elements.

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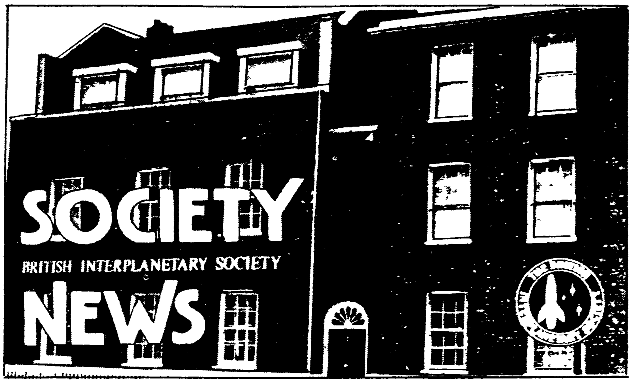
The research described in this article was performed by the Jet Propulsion Laboratory, California Insitute of Technology, under contract with the National Aeronautics and Space Administration. *Rodica Ionasecu is a member of the Technical Staff, Mission Design, JPL, and Paul Penzo is a member of the Section Staff, Mission Design, JPL.*



New Society President

Mr. G. W. Childs has taken office for 1988 as the new President of the Society, succeeding Mr. C. R. Turner whose three-year term of office has expired.

Mr. Childs graduated at Bristol University in aeronautical engineering in 1956 before joining the De Havilland Aircraft Company. In 1961, he became Senior Engineer, Design Department of the Space Division, BAC, carrying out design and development of the Blue Streak airframe as the first stage of the ELDO A launch vehicle as well as future ELDO project studies.

Mr. Child's career has continued to be closely involved with launch vehicle and spacecraft design. In 1980, he became Chief Engineer, Space and Communications Division, BAe, being responsible for the design, development and manufacture of spacecraft, vehicle systems and equipment, technology department and future studies. His present position is at BAe, Stevenage as Chief Engineer (Mechanical Equipment).

Mr. Childs has been a member of the BIS Council since 1983 and serves as Chairman of the BIS Space Technology Committee Group.

SPACE '88 – A Major UK Event

With arrangements now well in hand for *SPACE '88*, the Society's weekend meeting at Hastings, September 30 to October 2, 1988, another major opportunity is being created by the Society to promote the awareness if space and highlight its future potential. The theme of the meeting is 'Man in the 21st Century'.

"The Society has a proud record of achievement in its programme of meetings and conferences," according to the Society's newly-elected President, Mr. G.W. (Bill) Childs.

"It is a particular honour for me to accept the office of President at this time following the hosting by the Society of the very successful 38th International Astronautical Congress at Brighton last year together with the excellent Space '87 exhibition.

"Space offers unprecedented opportunities for international cooperation in high technology with benefits to science, telecommunications and other areas of technology, and the Society is concerned to see that new goals are identified and backed with the resources needed to maintain progress."

Commenting on the theme of the SPACE '88 meeting, Mr Childs said that man's activities in space in the 21st century related closely to future developments in launch vehicle technology as a means of achieving a more ready access to space at a much reduced cost.

"In the meantime it is particularly important to heighten public awareness of the long-term potential of space and generate the political will to pursue worthwhile long-range goals," he said.

SPACE '88 is open to both members and non-members of the Society. Like the Society's SPACE '82, '84 and '86 weekend meetings, ***SPACE '88*** promises to be a major UK space event and also to offer a pleasant social occasion. Further details may be requested from the Society (see p.180). Early registration is advised.

APPEAL – Latest Report

In May 1987 the Society launched its Appeal for £80,000 towards meeting the cost of a much-needed extension to its premises. At the end of its first year, we are pleased to report that the Fund has accumulated a sum of £21,845, this including £4,160 recovered by Deeds of Covenant and legacies from the late Mrs. I. V. Golovine and J. E. Hall.

As reported under Society News in January's issue of ***Spaceflight***, a separate programme of extensive repair work has been put in hand at the Society's HQ as a necessary pre-requisite to building the proposed new extension at a later date.

Good progress has been made with the repairs, but part of the facade of the building is still ensconced in scaffolding and further work remains to be done. When this is complete the new extension will fall in place as our next major undertaking. In the meantime, the Appeal for funds to meet the costs of a new extension will continue on all fronts.

When the Appeal was launched a year ago we gave it the banner 'More Space for Space'. Events have since emphasised the importance of the Society's role in promoting space and that our need for adequate facilities goes far beyond what can be met from regular income. Hence, the importance of the Building Appeal Fund and the value to the Society of the many donations that have already been received.

Your generous support will continue as ever to be gratefully received. Each contribution brings us one step nearer to the fulfilment of our plans. Please send to: The Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

Donations to the Library

We would like to record our grateful thanks to many members of the Society who have continued to support the Library by donating suitable material.

Among these are Curtis Peebles, who provided an inscribed copy of his book on "Guardians – Strategic Reconnaissance Satellites", and Captain R. F. Freitag, who provided the missing Vol. 4 of the series "Men in Space" by Shirley Thomas thus completing our set. Lester Winick continued to offer books and reports from his collection and Rex Hall has continued to send us Soviet First Day Covers. Two excellent IRAS pictures came from Ms. Jacqueline Souras and Ross Rugg sent three boxes of pre-war science fiction magazines, several of which contained interesting factual contributions by early space pioneers.

The Society is always interested in receiving offers of help in extending its Library, either in cash or in kind. A collection of back issues of ***Spaceflight*** for resale is gratefully acknowledged from Mrs. J. McIlmoyle, and so also is a collection of surplus books from Dr. King-Hele. The sale of such items helps to secure funds to enable us to acquire other items that we need.

The Library Working Group constantly seeks items for the Society's Special Collections and appreciates the support which members are giving to the Society's Extension Appeal, which includes plans for enlarging the present Library.

The Library is open on the first Wednesday of every month (except August) to coincide with the programme of Evening Meetings, an arrangement which has proved very convenient and extremely well received.

Black Knight Symposium

Britain's re-entry test vehicle Black Knight made its launch debut in September 1958 just three years and three months after its go-ahead was given and three years after industrial contracts were placed.

The events of the novel and successful programme of research into launch vehicle technology, conducted in the ensuing years up to 1965 at Woomera Rocket Range, were reviewed with nostalgic delight by speakers and audience at a well-attended one day meeting held at the Society's Headquarters on March 23, 1988.

Two Black Knight vehicles now remain as museum pieces according to Dr. John Becklake of the Science Museum, London, who chaired the meeting and is also Chairman of the Society's History Working Group. One is at Edinburgh and other is on loan to Liverpool from the Science Museum, which also holds four re-entry heads and other components.

The short time-scale of Black Knight's development was a remarkable achievement. The launch site facilities at Woomera were also swiftly constructed, being in place and ready, on previously undeveloped semi-desert within two years.

The speed of Black Knight's development was attributed to its non-military nature, yet benefitting from Blue Streak's priority as an ICBM. In addition, the project team at the Royal Aircraft Establishment (RAE) were given a free hand in all design matters and their implementation, and RAE's long-standing experience with test vehicles was a great asset. Above all, the quality of the teams involved and their willingness to work long hours were seen as main factors contributing to the success.

Close cooperation with the US during these years (1959-1965) with frequent exchanges of ideas confirmed Britain's leading position in re-entry technology. Results from the Black Knight programme were used on the US Jupiter C. A great advantage for Britain was in the use of Woomera Range with its excellent recovery facilities, whereas a 'land' range had always been denied to the US for re-entry research.

An off-shoot of the programme was its value in training a new generation of people with space experience, but unfortunately, Britain was subsequently to give up its position as the world's third space power. Nowadays Britain's inability to capitalise on the advances made through the 1950's and 1960's strikes a particularly sad note when the current world market for launch vehicles is considered.

The speakers and programme for the meeting were as follows: Chairman: John Becklake (Science Museum); Assistant Chairman: James Goddard (Science Museum); Dr. J. Becklake (Introduction); Mr. H. Robinson (Overview of Black Knight Project); Mr. J. Scragg (Black Knight – A Contractor's View); Mr. D. Andrews (Propulsion for Black Knight); Mr. J. Harlow (Black Knight – Upper Stages); Mr. R. Dommett (Black Knight Payloads); and Mr. H. Robinson and Mr. R. Bain (Proposals for the Development of Black Knight).

A. D. Baxter

It is with deep regret that we record the death of Professor A. D. Baxter, a Fellow of the Society of 40 years standing. Professor Baxter was Superintendent of the Rocket Propulsion Department of RAE, Farnborough at Westcott (later to become the Rocket Propulsion Establishment) before becoming Principal of the College of Aeronautics at Cranfield, now known as Cranfield Institute of Technology.

Deeds of Covenant

Members who pay UK income tax are earnestly requested to complete a Deed of Covenant to enable the Society to recover the tax that they have already paid on income equal to the amount of the payment and which would otherwise be lost completely. An appropriate form is available from the Society and its completion is a simple procedure. Members can benefit the Society in this way at no additional cost to themselves.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

4 May 1988, 7-9 pm — **Lecture**

HISTORY OF THE ROYAL OBSERVATORY

A.J. Perkins

Flamsteed, Halley and Bradley, the first three Astronomers Royal, need no introduction to anyone with an interest in the history of astronomy. The seventh Astronomer Royal, G.B. Airy, has his own renown but his life and work at the Royal Observatory, stretching over 46 years, are not well documented. Tracing the history of the Observatory at Greenwich from its foundation in 1675, Mr Perkins will show in his talk how Airy's achievements and setbacks have affected the development of the establishment up until the present day.

Admission by ticket only. Members should apply in good time enclosing an SAE.

4 June 1988, 10-4.30 — **Symposium**

SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

25 June 1988, 2 pm — **Visit**

RAF Cosford Museum

This will be a special afternoon tour, limited to 25 members. Registration details and further information available from the Society. Please enclose SAE.

6 July 1988, 7-9 pm — **Lecture**

SUPERNOVA 1987A

A.T. Lawton

Members only. Please apply for ticket, enclosing SAE, in good time.

14 July 1988, 10-4.30 — **Symposium**

EXTENDING THE SPACE INFRASTRUCTURE

The reports of the National Commission on Space and Dr. Sally Ride have paved the way for a new innovative space policy in the United States. It encompasses the setting up of bases on the Moon and manned exploration of the planet Mars. The BIS is holding a two part symposium on the issues raised by this exciting new prospect.

The purpose of the symposium is to start European discussion on the subject, including a review of American proposals, and proposals for suitable European contributions to the programme.

The symposium covers the following subjects:
- Infrastructure planning
- Orbital transfer systems
- Geostationary operations
- Lunar transportation system
- Lunar bases
- Planetary exploration systems
- Exploitation of the solar system.

The first part of the symposium will be held on 14 July 1988 and the second part will be held on 15 November 1988.

Offers of Papers are invited
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Society. Please enclose SAE.

30 Sept – 2 October 1988 — **Conference**

SPACE '88

Major weekend space conference, including varied programme of lectures and full social programme.

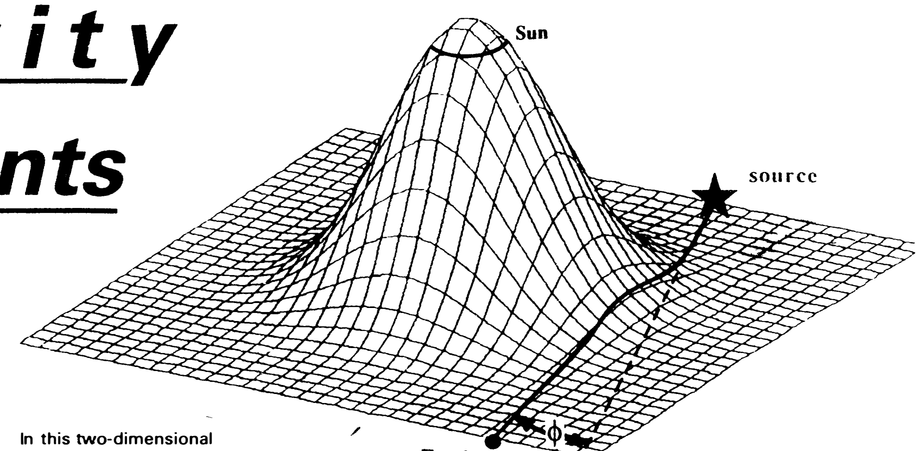
Venue: White Rock Theatre, Hastings, Sussex, UK

Registration
Forms and further details are available from the Society by sending 20p stamp or international reply coupon.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

Relativity Experiments



In this two-dimensional drawing, an attempt is made to represent the curvature of four-dimensional spacetime in the vicinity of the Sun. Light from a star would travel a curved path, and the star would appear to be slightly displaced from its expected position on the celestial sphere. This effect, predicted in 1916 as a consequence of Einstein's theory of General Relativity, was first observed during a solar eclipse in 1919. *NASA/JPL*

In the over 70 years since Albert Einstein (1879-1955) published his General Theory of Relativity, this intellectual edifice has successfully passed every experimental test to which it has been subjected. Einstein himself put forth three consequences of his theory which would provide experimental verification: (1) a slow rotation in the orbit of Mercury which had been observed but remained unexplained in terms of Newton's theories of gravitation and dynamics, (2) the slight bending of starlight as it passed close to the Sun; this effect was dramatically confirmed in a solar eclipse expedition of 1919 when stars close to the solar limb were observed to be slightly displaced from their expected positions, and (3) a small shift towards the red end of the spectrum of electromagnetic radiation emitted from a massive body such as the Sun; this effect was not definitively verified until the 1960s.

Gravitational theory and General Relativity are inextricably linked; it was Einstein's great achievement to geometrise the effects of mass by representing gravitational force by the warping it induces in the fabric of space and time. In two-dimensional space it is easy to cite examples of curved space, e.g., the surface of our Earth. For more dimensions, the mathematical discipline of Riemannian geometry, developed prior to its application to physics, furnishes the appropriate tool.

Ten years earlier, in 1905, Einstein published his theory of Special Relativity, which treated the physics of reference frames moving with constant velocity with respect to one another and predicted such startling phenomena as the slowing of a clock as its velocity increased towards the speed of light. Ironically, Einstein received his Nobel prize for physics in 1921, not for his creation of relativity theory but for his work on the photo-electric effect in quantum theory. It was felt that his relativistic work was too controversial!

Sir Isaac Newton – artistic representation by *Julian Baum.*

The General Theory is, along with the quantum theory of subatomic particles, a foundation stone of modern physics. In addition, it is an important theoretical tool in understanding astrophysical phenomena such as black holes and other states of gravitational collapse. General Relativity is not the only theory of space, time, and gravitation which has been proposed. Numerous alternative theories have arisen; some have fallen by the wayside, others remain as legitimate contenders. In the weak gravitational environment of the Solar System, all relativistic theories differ only slightly in the magnitude of the subtle effects they predict. Hence, it is necessary to conduct high-precision experiments to differentiate between competing theories or to study phenomena in this domain.

Newton's apple has travelled a long way in 300 years.

Dr. Ronald W. Hellings of JPL specialises in gravitational and relativity theory and is active in formulating and conducting experiments in support of NASA's programmes in this area. We discussed three regions which are being actively pursued: experiments to test the validity of competing relativistic theories; detection of a weakening of gravity throughout the universe with the passage of time, should this hypothesised trend be real; and detection of gravitational waves – a phenomenon predicted by the General Theory of Einstein (and other theories of relativity).

The General Theory is a "metric theory" of relativity, as are most, but not all, theories of relativity which have been proposed. A metric is a mathematical rule which allows one to calculate the distance between two points. Since Einstein utilised space and time welded together in a single four-dimensional manifold (three dimensions of space and one of time), the points calibrated by a metric lie in four-dimensional "spacetime".

In everyday life, a common metric for measuring the distance between two points goes back at least to the Greek philosopher and student of geometry, Pythagoras (c.582 to c.497 B.C.) The Pythagorean theorem states that the square of the length of the hypotenuse of a right triangle equals the sum of the squares of the lengths of the two sides; this theorem yields a metric by providing a way to measure the distance between the two points at the ends of the hypotenuse, given the lengths of the sides.

It turns out that this way of looking at metrics, when suitably generalised, is useful for characterising the stucture of spacetime in relativity theory. What is done is to write a mathematical expression, generally analogous to the form of the Pythagorean expression, for the distance between two very-close-together points in four-dimensional space. Two neighbouring points are picked because additional mathematical effort is required to undertake the job of expressing the distance between more widely separated points.

In the absence of matter, spacetime is described by the tenets of ordinary

Euclidean geometry, which includes the Pythagorean-type metric. Introduction of matter into the situation produces distortions (for Euclidean geometry) in the spacetime manifold, and the applicable geometry must be built up from more complex metrics: that of the General Relativity of Einstein or a competing relativistic theory. For the purpose of experimentally testing the various theories of relativity in a Solar-System setting, an approximate formulation has been devised which includes all metric relativistic theories as special cases. The "Parametrised Post-Newtonian" (PPN) formalism in its usual formulation employs ten parameters to express relativistic deviations from the Newtonian description wherein Euclidean geometry applies. Each metric theory of relativity, including that of Einstein, predicts a certain numerical value for each of the PPN parameters. Thus, precise experimental determinations of these parameters can serve to reject a particular theory or provide additional confidence in its correctness. The PPN formalism serves as a good approximation only when extremely massive or fast-moving bodies are not present, an approximation that is true in the Solar System.

The PPN parameter designated by the Greek letter gamma can be interpreted as a measure of the curvature of space (Euclidean space is "flat", with no curvature). General Relativity predicts a value of exactly 1 for this parameter. To date, the best numerical determination of gamma was done by carefully measuring the time of signal passage between stations on Earth and the Viking Landers on Mars, yielding an accuracy of the measurement of gamma within 0.2 percent. The time delay of signals is a consequence of the curvature of spacetime, because the path length is longer than in flat space. Similarly, the bending of starlight near the massive Sun is related through gamma to the curvature of space (the Sun significantly warps spacetime in its vicinity, and thus light rays passing close to that body are affected).

The slow rotation of planetary orbits, fastest in the case of Mercury which is close to the Sun (but the rotation only amounts to 43 seconds of arc per century), involves the sum of gamma and a second parameter, beta. Careful analysis of combined Solar System data from many space probes and the analysis of planetary orbits has resulted in the estimation of beta to an accuracy of 0.9 percent.

Further knowledge of the value of PPN parameters and the testing of competing theories of relativity could be attained by landing a radio transponder on the asteroid Icarus, which crosses the Earth's orbit and penetrates deeply into the Sun's gravitational field as it plies its eccentric orbit. A spacecraft in an orbit about Mercury would also be of utility in PPN investigations (see the February 1988 edition of this column for notes on a mission to Mercury). These two experiments would yield a factor of 10 to 100 improvement in our knowledge of gamma and beta.

Another test of relativity, outside the domain of the PPN formalism, would be provided by placing a gyroscope in Earth orbit. Relativity predicts that a moving mass generates a field that deflects a second mass moving through the field. In the present case, the Earth rotating on its axis would furnish the first moving mass, the gyroscope the second. Since the interaction is mathematically similar to the generation of a magnetic field by a moving electric charge and the consequent deflection of a second electric charge moving in the field, it is often termed a gravito-magnetic effect. Hellings said Gravity Probe B (GPB) is a proposed NASA mission that would place four superconducting gyroscopes in Earth orbit and, after one year of tracking, yield an accuracy of measurement of the General-Relativistic-predicted gyroscopic precession to about the 1 percent level.

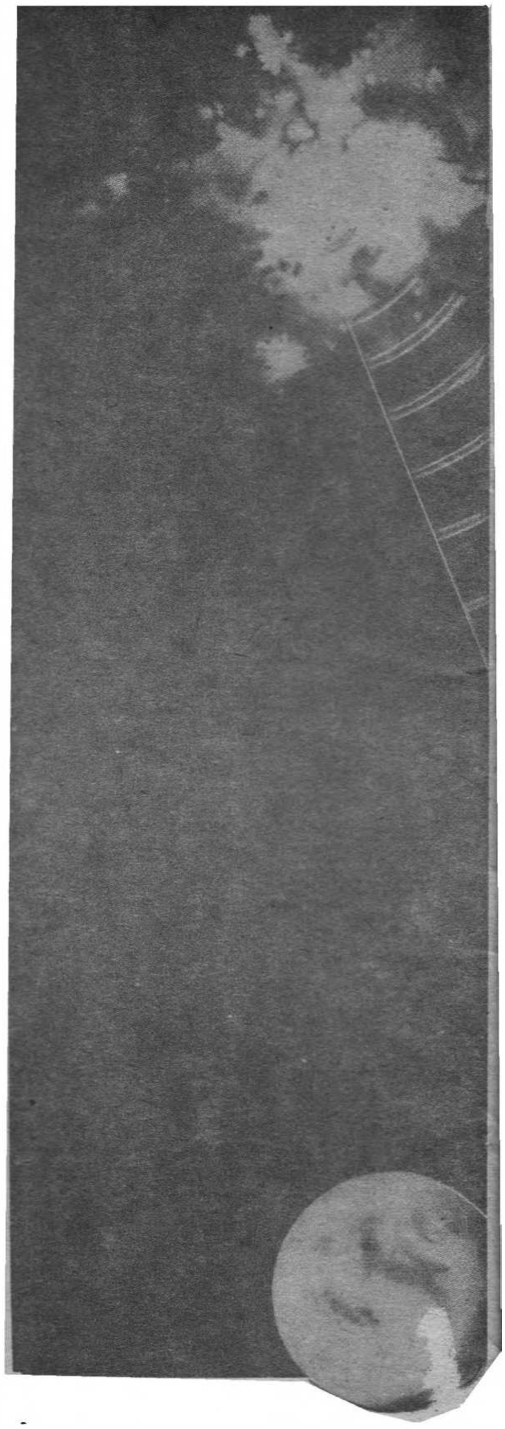
Our second major area of discussion, after the subject of testing of relativistic theories, focused upon the possible weakening of gravity as a force as time passes.

There are four fundamental forces in the universe. They are, listed in order of decreasing strength: the strong force, electromagnetic force, the weak force, and gravitational force. The strong and weak forces are confined to the nuclei of atoms, while the other two are unbounded in extent. Einstein attemped without success to develop a theory which unified gravitational force with other forces in one explanation. So far, from work done by Weinberg and Salam, the electromagnetic and weak forces have been unified and explained as manifestations of a single "electroweak" force.

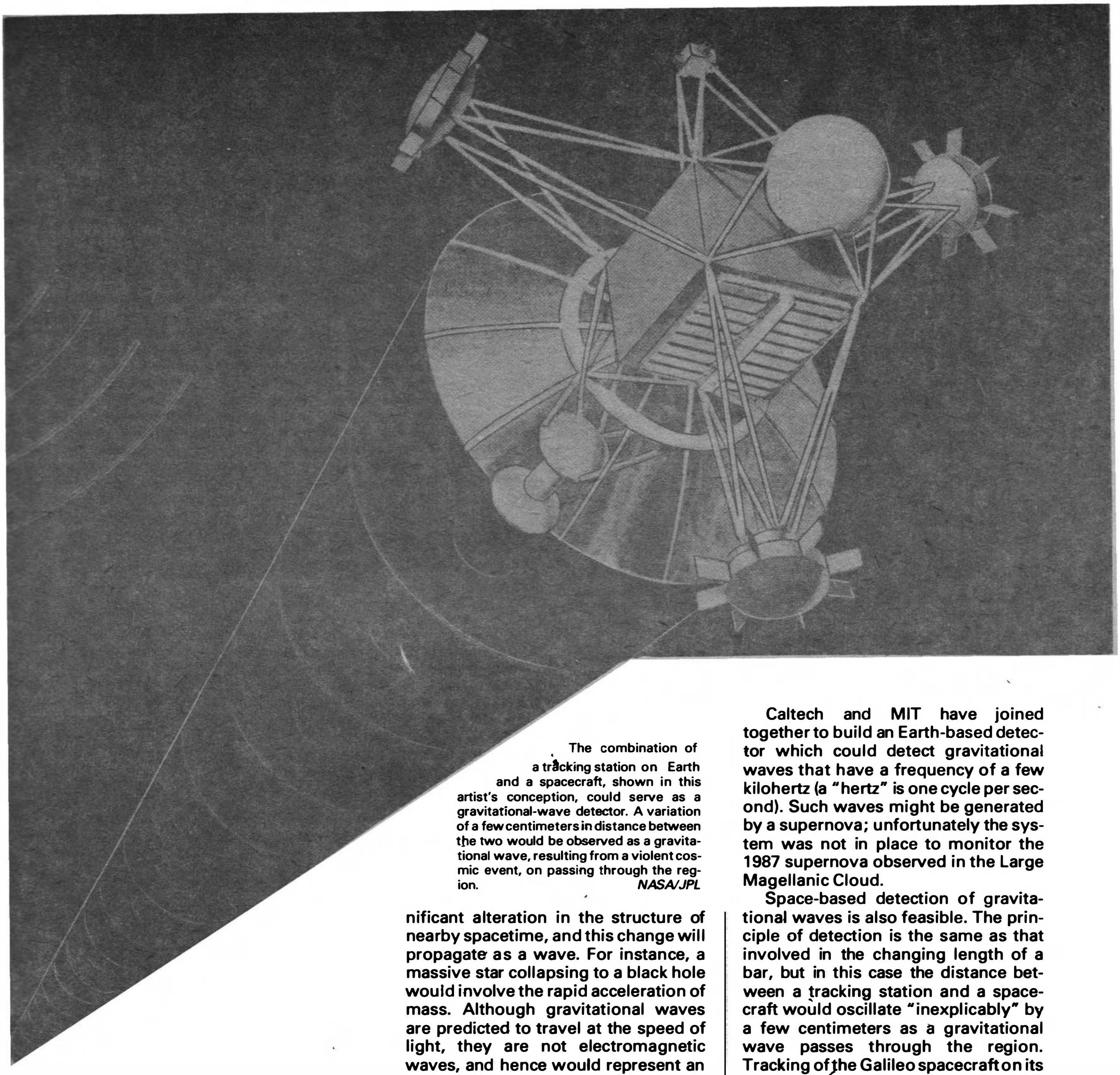
Efforts are underway to unify the first three forces into a "Grand Unified Theory", referred to as "GUT" in the literature. The final step, which is being addressed even prior to achievement of a generally accepted GUT, is the unification of all four forces; such efforts are appropriately entitled "Theories of Everything", genera of which are supersymmetric string theory and Kaluza-Klein theories.

The last-named theories have postulated that our observed four-dimensional spacetime constitutes the bulk of a higher dimensional manifold (an 11-dimensional manifold is discussed in an article by D.Z. Freedman and P. van Nieuwenhauizen in the March 1985 *Scientific American*) which is still evolving and changing the value of the gravitational constant G which measures the strength of gravity.

Unlike the precise predictions of relativity theories, cosmologists have not settled on a precise prediction for the fractional variation in G, but it is estimated to be less than one part in 100,000 million per year (and could be 0).



An exciting chance to measure the possible variation in G will come with the Soviet Union's mission to the Martian satellite Phobos. Two landers are scheduled to be placed on this small satellite early in 1989 in order to undertake a variety of scientific investigations. Careful tracking of the landers from Earth for a period of time will enable one to detect possible variations in G at a lower threshold than any determination to date. After one year of



The combination of a tracking station on Earth and a spacecraft, shown in this artist's conception, could serve as a gravitational-wave detector. A variation of a few centimeters in distance between the two would be observed as a gravitational wave, resulting from a violent cosmic event, on passing through the region. *NASA/JPL*

tracking, current sensitivities in detecting variations in G would be surpassed; after five years an order-of-magnitude improvement is expected, and variations as small as one part in a million million per year would be detected. Hellings, who is a member of the Phobos Lander science team along with Drs. John D. Anderson, John M. Davidson, and Robert A. Preston of JPL, said that the experiment would combine Mariner 9 and Viking data with the Phobos data set to obtain the indicated results.

Gravitational waves were predicted long ago as a consequence of Einstein's field equations. If a large mass is rapidly accelerated, it will induce a significant alteration in the structure of nearby spacetime, and this change will propagate as a wave. For instance, a massive star collapsing to a black hole would involve the rapid acceleration of mass. Although gravitational waves are predicted to travel at the speed of light, they are not electromagnetic waves, and hence would represent an entirely new channel of information about the astrophysical universe.

Dr. Joseph Weber of the University of Maryland has been a pioneer in the effort to detect gravitational waves experimentally, but his results have not been verified by other workers in the field, and the general consensus is that a definitive detection of gravitational waves remains to be accomplished.

A common device employed as a gravitational-wave detector is a bar placed perpendicul r to the supposed source of waves. As the "ripple" in spacetime passes through the region where the bar was located, its length would change very slightly.

Caltech and MIT have joined together to build an Earth-based detector which could detect gravitational waves that have a frequency of a few kilohertz (a "hertz" is one cycle per second). Such waves might be generated by a supernova; unfortunately the system was not in place to monitor the 1987 supernova observed in the Large Magellanic Cloud.

Space-based detection of gravitational waves is also feasible. The principle of detection is the same as that involved in the changing length of a bar, but in this case the distance between a tracking station and a spacecraft would oscillate "inexplicably" by a few centimeters as a gravitational wave passes through the region. Tracking of the Galileo spacecraft on its way to Jupiter (a 1989 launch is scheduled) could detect gravitational waves with frequencies in the millihertz range. Such waves might be generated by a mass equalling ten thousand to one million Suns collapsing to form a black hole at the centre of a galaxy.

Recent years have seen an upsurge in relativity theory as the technical means for carrying out experiments have greatly improved. Also, astrophysical applications have grown from their original status as interesting curiosities concerning small effects to integral portions of major events. Newton's apple has travelled a long way in 300 years.

The two Voyager spacecraft are tied to Earth via electronics and the watchful eyes of a Voyager ACE (John Tullius) on the Mission Control Team. NASA/JPL

Voyager Flight Operations

The nerve centre of Voyager flight operations is located in a small glass "cage" on the fifth floor of the Space Flight Support building at JPL. The cage is occupied by the on-duty ACE who maintains a close relationship with two spacecraft that are exploring the outer reaches of the solar system. His primary job is to make sure that the data transmitted from those distant spacecraft are finally delivered to the correct addresses on Earth. From this place, commands are also started on their way toward the spacecraft to guide the production of more scientific and engineering data for Earthly consumption.

The Voyager project is organised into five "offices" whose managers report to the Mission Director. In the November 1987 issue we discussed some spacecraft and ground capability enhancements which were directed by the Flight Engineering Office and the Ground Data System Engineering Office, respectively, while the March 1987 issue featured the role of the Mission Planning Office in guiding the encounter of Voyager 2 with Neptune in August 1989. The fourth Voyager office, Flight Science, was represented with regard to its role in science planning in the March 1988 edition of this column.

Stepping down one level in the hierarchy we encounter Voyager "teams". The ACE position is resident in the Mission Control Team of the Flight Operations Office (FOO), the fifth Voyager office and our topic for discussion this month. The term "ACE" is used by the project to denote the lead nature of this position.

It is not only important to make sure that all scheduled data are, in fact, routed to their correct destinations within the project but that data being received are of good quality. One parameter that is constantly monitored is the signal-to-noise ratio of the spacecraft's radio transmission, as seen by a tracking antenna of the Deep Space Network. If this parameter falls too low, an unacceptable number of bit errors will creep into the data stream. A second indicator of potential problems with data quality is the deviation of the measurements conveyed by a specific telemetry channel from long-term trends, for no apparent reason. This could, of course, indicate trouble onboard the spacecraft. But in the vast majority of cases, deviations of this nature are indicative of a problem somewhere within the ground system: a computer has gotten out of step.

Terrence P. Adamski is the manager of the FOO (yes, normal Voyager usage also pronounces it as one word rather than calling out the letters of the acronym one-by-one). He assumed this role after the Voyager encounter with Uranus in 1986; for that event he had served as Deputy FOO Manager. Except for a 1 ½ year stint on AMPTE operations after the Voyager encounter with Saturn, he has been with the Voyager project since 1978, joining the Mission Control Team as an ACE in April of that year.

There are several challenges that Adamski foresees for the Voyager 2 encounter with Neptune. Foremost is the extensive amount of updating of onboard command loads that the project is contemplating. These updates are employed to ensure the latest information is loaded into the memories of the onboard computers to guide scientific observations during critical mission phases. Typically, the latest estimates of the trajectories of the spacecraft, natural satellites, and planet are crucial for accurately pointing instruments when close encounters are planned; at close range, a small error in instrument pointing can result in lost opportunities. The Neptune encounter will be particularly difficult because it is, in a sense, a dual-planet encounter: first Neptune and then, a few hours later, the large satellite Triton.

For scheduled updates, after Flight Science and Engineering Office personnel have determined what command changes must be radioed to Voyager 2, it is the responsibility of the FOO to coordinate delivery of the new

information to the spacecraft. In order to appreciate this responsibility, it is helpful to understand something about the process of transmission of commands to Voyager 2.

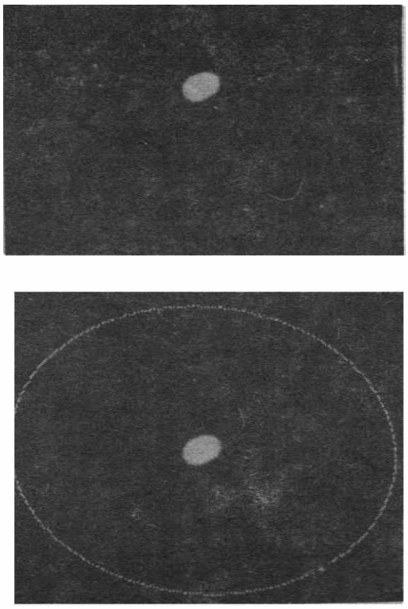
Broadly speaking, two categories of commands are uplinked to the spacecraft: (1) sequence loads, which are a full set of instructions to guide the activities of the spacecraft for a period of days or weeks, and (2) updates or supplements to these sequence loads (see "How to Feed a Spacecraft" in the January 1987 edition of this column).

Compared to rates of data transmission from the spacecraft, often several kilobits per second, commands are sent to the spacecraft at a slow rate: 16 bits per second. Thus, considering the size of a typical Voyager sequence load, it takes on the order of an hour to install one of these loads in the onboard computer of the spacecraft. The sequence load is actually split into "blocks" (60 to 75 comprise one load) for transmission, each block taking 50 seconds to transmit. These blocks are counted by the spacecraft as they are received and, normally, execution of this new sequence load is not begun until the spacecraft has received all of the blocks: the so-called "conditional execute" mode (occasionally, an unconditional execute strategy is indicated by the mission situation).

The ten sequence loads that will span the Neptune-encounter period, from June 5 through October 2, 1989, each have an "uplink window" allocated to them: the period of time during which the load must be transmitted to the spacecraft from antennas of the Deep Space Network. These windows will range from as short as 16 hours to as long as 22 hours. Too long an uplink window would necessitate an excessive dead time between the old sequence load and the new one, an inefficient use of valuable observing time.

Adamski said that a strategy of multiple transmissions of each load will be employed during the Neptune encounter, as at previous planetary encounters for Voyager. Since the round-trip light time at encounter with Neptune will be approximately 8 hours, a significant fraction of the uplink window, one should not wait to see if the entire load has been received by the spacecraft. Each encounter load will be transmitted at least six times. In this fashion, any blocks that might not have been received by Voyager 2 from the first transmission will almost certainly be filled in by later ones.

The process is not as unreliable as one might infer from the number of load transmissions; complete reception of a sequence load is crucial to mission success, and the added insurance comes at little cost. However, reception of commands by Voyager 2 is not as straightforward as one might wish. In 1978, the spacecraft had to be switched to its backup receiver after a failure of the primary receiver, and this



The large satellite Triton is shown in orbit about Neptune in this image taken from Voyager 2 on January 16, 1987 when the spacecraft was 1,373,000,000 km from the planet. The orbit of Triton was inscribed by an artist, and the image of Neptune is elongated due to smear during this 5.76-second exposure. *NASA/JPL*

receiver was found to have a failed tracking-loop capacitor, which reduced the acceptance bandwidth by a factor of 1000 from the designed value. As a consequence, the centre of the reduced acceptance bandwidth must be very carefully measured by the Spacecraft Team (in the Flight Engineering Office) at critical points during the mission so that transmissions will, in fact, be successfully received. This centrepoint drifts over a wide range of frequencies, largely due to thermal events induced by power switching of onboard electrical devices, motor burns, and spacecraft turns.

Each Voyager spacecraft is currently tracked for an average of 17 or 18 hours a day.

Let us now return to the subject of updates to sequence loads. The most challenging member of this category is, in Voyager terminology, a "Late Stored Update" (LSU). At Uranus, one LSU was performed just prior to the closest approach of Voyager 2 to the planet. It was the culmination of 30 hours of intensive ground activity wherein the latest tracking data were converted into new navigational estimates and thence into a few appropriately updated blocks which were sent to the spacecraft, arriving just a few hours before they were executed. At Neptune, three LSUs are planned in order to meet the objectives, especially in radio science and imaging, of this "dual encounter".

The key to the success of an LSU lies in careful planning of the required series of ground actions by the flight team and thorough rehearsal of these actions. Your correspondent, who was manager of the Flight Engineering Office for the Uranus encounter, experienced an extraordinarily tense time on October 23-24 of 1985 as we struggled all night to get the LSU-rehearsal load completed and transmitted to the spacecraft. My journal shows for the early morning hours of the 24th the entry: "I spoke with the FOO, and they greased the skids to get the sequence up as late as possible in the Madrid uplink window" (the Deep Space Network has a station in Madrid, Spain). We got the load up with only 10 minutes to spare, after 30 hours of effort! Procedural problems were corrected, and a second rehearsal on November 9 went smoothly, as did the real encounter in January. It was very comforting to have the resourceful services of the FOO available during the tough times.

The data-receipt functions of the FOO are not exhausted by the role of the Mission Control Team, which we might characterise as monitoring and routing real-time data. The Data Management Team of the FOO is responsible for data which have less stringent time constraints associated with their handling. This team ships data to scientific investigators, makes data available to engineering elements of the flight team for in-depth analysis, and performs data archival functions.

A precondition for either the reception of data on the ground or the transmission of commands to the spacecraft is the scheduling of an antenna (or array of antennas) to track the spacecraft. The scheduling of time on the network for the two Voyager spacecraft must be done in conjunction with the tracking needs of other operating spacecraft such as those in the Pioneer series, AMPTE, and ICE. The negotiation process is complicated by the fact that Voyager sequence loads must be planned in detail months in advance of their execution. This places significant constraints on scheduling, and Adamski's staff devotes a good deal of time each month in tracking-schedule planning and in negotiations for tracking coverage with other flight projects. Each Voyager spacecraft is currently tracked for an average of 17 or 18 hours per day in order to capture its unique information about conditions in the outer Solar System and to monitor its engineering state.

After the encounter with Neptune, the hectic pace of planetary operations will cease forever for the Voyager project. But the region beyond the planets contains information of great scientific interest, and even the drama of an encounter could return if the spacecraft pass through the heliopause. – that hypothesised region where the influence of the solar wind terminates – before the end of their operational lifetimes.

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The International Magazine of Space and Astronautics

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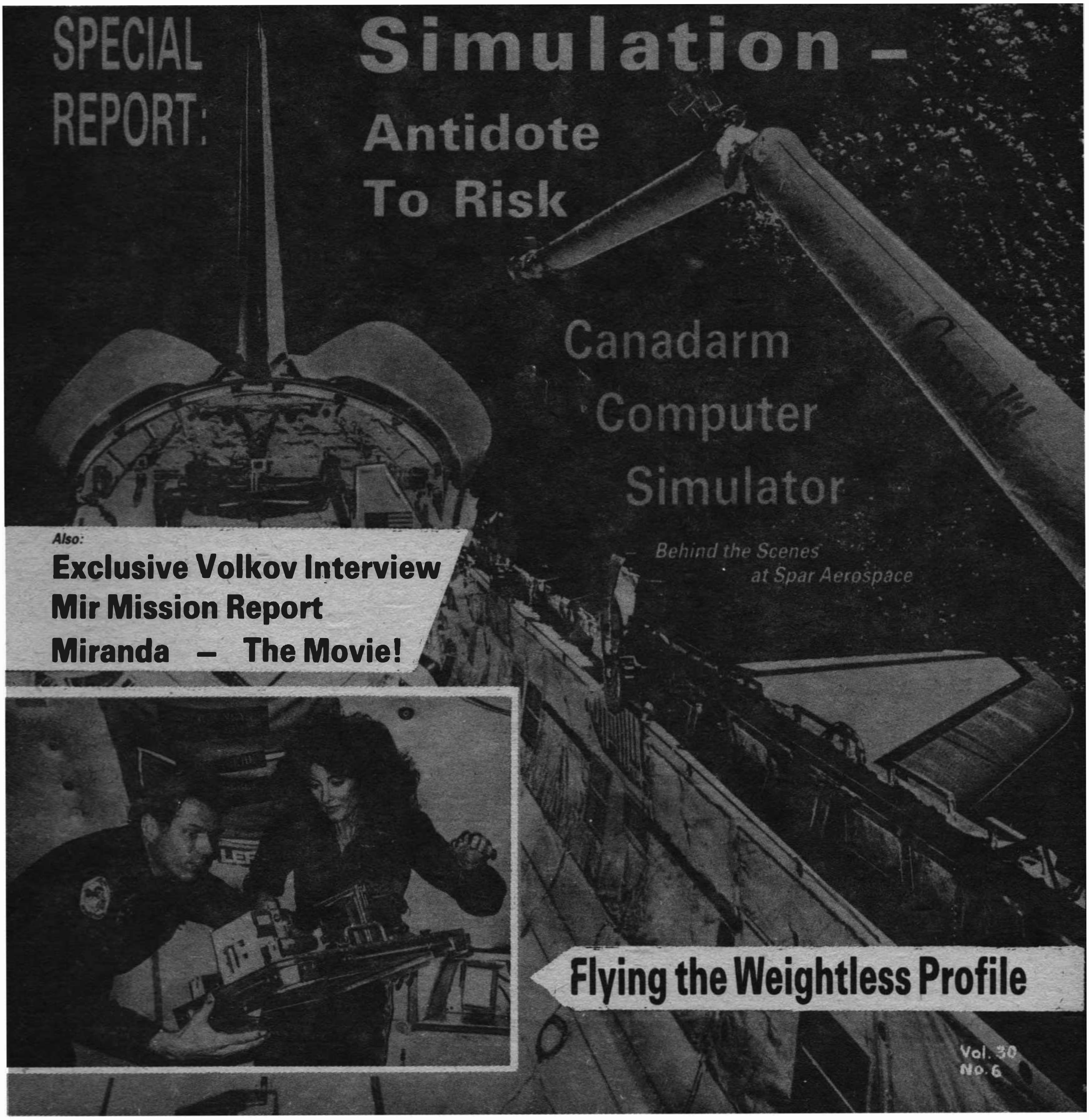

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Vol. 30 No. 6 June 1988

Front Cover: Space simulation, the theme of this month's issue, plays a key role in all kinds of space missions. The Canadarm, depicted in the main picture, has its own simulation facility which is the subject of a feature on p 244. The inset picture shows astronaut Byron Lichtenberg at work during a zero-G profile in NASA's KC-135 plane, and on p.248 BIS member Curtis Peebles reveals how he experienced weightlessness flying in a light aircraft.

Volkov Prepares for Autumn Flight

Alexander Volkov.

Barnsley, a South Yorkshire mining town in the heart of England, may not be familiar to many *Spaceflight* readers. But for one week in April 1988 it played host to a delegation from its twin town of Garlovka in the Ukraine, USSR. Amongst the delegation was one of Gorlovka's most famous sons – Hero of the Soviet Union, Pilot Cosmonaut of the USSR, Colonel Alexander Volkov, veteran of a two month space mission in 1985 and due to command an international mission to Mir later this year.

Among many engagements, the delegation visited Hoyland Kirk Balk School in Barnsley to see pupils working at their weather satellite monitoring station and, at a meeting of the British/Soviet Friendship Society, Volkov showed a documentary film about Star Town and slides of the Earth from space.

Regular *Spaceflight* correspondent *Neville Kidger* took advantage of this unique opportunity to talk openly with Alexander Volkov, whose 1985 flight was cut short after his commander, Vladimir Vasyutin, fell ill. And, reflecting the importance of Soviet activities on the current space scene, this month's *Spaceflight* begins with his exclusive Volkov interview, followed overleaf with the latest Mir Mission Report, picking up activities since those covered in the March 1988 (p.113) issue.

I met Alexander Volkov at his hotel in Barnsley and started by asking him about when he first became interested in space. He was almost 13 years old when Gagarin made his flight and Volkov called the event a "spur to all men and boys". However, the thought of flying into space himself was, at that time, a crazy idea, although he recalled his ambition as a teenager to become a military pilot. In 1970 he graduated from the Kharkov Higher AF School and then served as a pilot instructor there for five years.

When the chance to apply as a cosmonaut came, Volkov felt that he was in full command of the situations he found himself in as a pilot and also physically fit. He was successful in his application and was enrolled in the cosmonauts' detatchment in February 1976.

His first flight assignment was to be a mission to Salyut 7 with Vasyutin and Savinykh. Part of the flight plan called for the erection of a new set of solar panels and tests of a beam erection device. Volkov and Vasyutin trained for the space walks needed for these tasks, and Savinykh trained for the solar panel EVA.

However, Salyut 7 went out of control before the team could be launched and Savinykh was paired with Dzhanibekov to fly a rescue mission and to install the solar panels. This was accomplished in June and August 1985.

Vasyutin and Volkov were joined by Georgi Grechko for their launch on Soyuz T-14 to Salyut 7 on September 17, 1985. Volkov told me that the reserve crew for the flight was Alexander Viktorenko, Gennadi Strekalov and a cosmonaut who has since been disqualified due to medical reasons, after failing one of the training courses.

Following a short joint flight with Dzhanibekov and Savinykh, Soyuz T-13 returned to Earth with Dzhanibekov and Grechko leaving the original team of Vasyutin, Savinykh and Volkov on Salyut 7. The flight was due to end on March 16, 1986.

They then received the Cosmos 1686 module which Volkov said looked much like the Mir Kvant module but was somewhat larger with an additional section added. Pictures have been published of the module, he said.

Exclusive interview by Neville Kidger

I asked him about Vasyutin's illness which led to early termination of the flight. Volkov stressed that he could not diagnose the illness because he was not a "medical person" but did say that Vasyutin had "some internal problem" and suffered "acute pains".

During this period Volkov and Savinykh lobbied controllers to allow them to conduct the beam device EVA but permission was refused. The three returned home in Soyuz T-14 on November 21, 1985, with Volkov, who helped pilot the spacecraft home, having completed 64 days 21 hours and 52 minutes in space.

His next assignment was as the reserve Commander of Soyuz TM-4, with Flight Engineer Alexander Kaleri and Cosmonaut Researcher Alexander Shchukin, the latter now involved in the Soviet Space Shuttle programme. Shchukin and Alexander Levchenko, the prime crew's pilot, were introduced to Volkov about a year before the flight, he said.

Volkov expressed a "great ambition" to fly the Soviet reuseable spacecraft but said that at present he was "fully engaged" in the Mir programme.

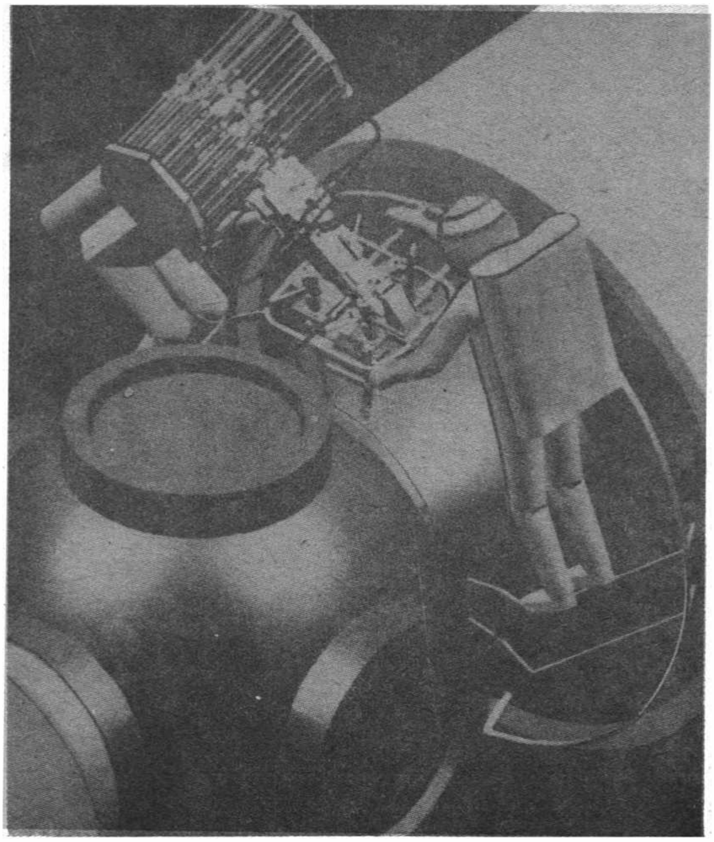
When I asked about his next flight he said he had "crossed fingers". It is currently scheduled for late November of this year and he will be accompanied by a Flight Engineer whose identity he did not know at the time of the interview (Kaleri, he said, was just not ready for a long period flight yet), and a French cosmonaut, Jean Loup Cretien.

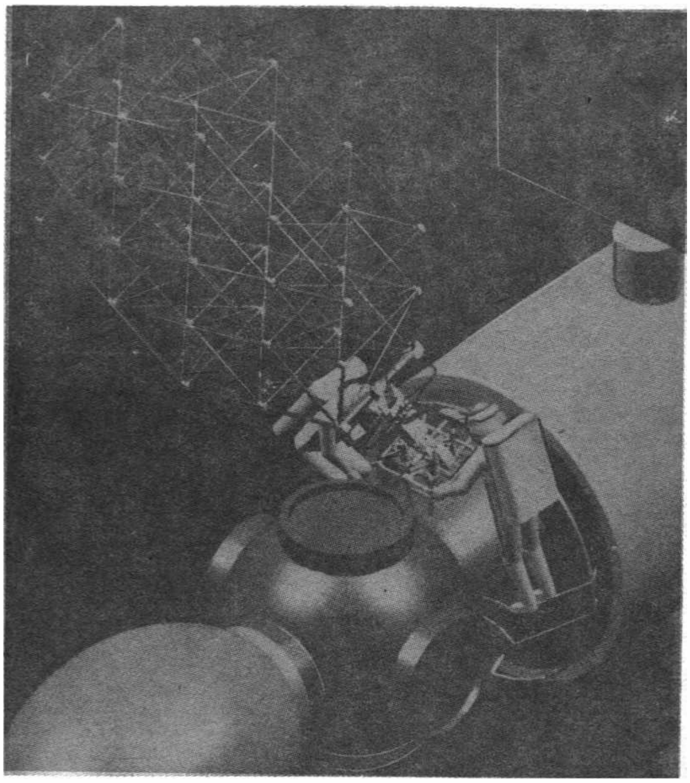
The French cosmonaut is scheduled to conduct an important EVA (see opposite) and Volkov is expected to make the EVA with him, although conformation is to be made. Volkov expects to learn the name of his Flight Engineer shortly after returning to training.

At the end of the year, or in early 1989 he expects a new module to be sent to Mir which will contain new life-support systems which Volkov and his colleagues will test. The module will also be equipped with a n MKF-6M multispectral camera system made by Karl Zeiss Jena of the GDR. Kvant was to have one of these but, Volkov said, the managers changed their minds on the matter (the model of Kvant displayed at the Paris Air Show last year had an MKF-6M camera system shown in it). The new module will also carry a most unusual cargo of Japanese Canaries for experiments, he revealed.

Finally, I asked if there were any amusing incidents that had occurred to Volkov during his 1985 mission. One thing that came to mind was the nicknaming of an extractor fan "The Bermuda Triangle" – because all things lost on the station seemed to turn up there! One day, Volkov recalled, he had lost his favourite spoon and by the next morning it still had not appeared at the "Bermuda Triangle". He asked Savinykh, who was in charge of the stores on Salyut 7, for a new spoon. The Flight Engineer warned Volkov "very strictly" that it was the last spoon he was to receive, because he was not "reliable!" Two days later the original spoon turned up on the fan and he found it. However, he did not return the new one to Savinykh in case he lost it again. "It is very difficult to be in space without a spoon," he said, smiling.

France's Mir Mission





Computer Simulations of EVA

The computer graphics (CAD) illustrations above show clearly the EVA task awaiting Frenchman Jean-Loup Cretien and cosmonaut Alexander Volkov during the joint Franco-Soviet mission to Mir at the end of this year.

The structure to be deployed has been built by Aerospatiale and consists of carbon fibre bars (see illustration in *Spaceflight*, December 1987, p.405) stowed in a small bundle and then extended by remote control to a diameter of 3.8 m to test the behaviour of the structure and its mechanism in space.

The CAD displays are examples of work produced at Aerospatiale's design office, pictured below.

• ***Computer Simulation feature – see p.240.***

SOVIET SCENE

Bulgarian Set for Mir Visit

A major space walk involving both Mir cosmonauts proved a highlight of the mission activity covered in *Neville Kidger's* latest Mir report below, which follows on from the March 1988 edition of *Spaceflight* (p.113). Over the coming months manned activity is to be stepped up with a series of joint international missions to the Mir complex. The first, involving a Bulgarian cosmonaut, has now been brought forward to June 7. August will see an Afghan cosmonaut flying to Mir and November a planned 30-day stay for Frenchman, Jean-Loup Cretien. On the unmanned front, next month (July) will see the long-awaited launch of the Soviet Phobos probes to Mars and its moons.

Okeans in Orbit

Highlight of the first months of the flight of cosmonauts Vladimir Titov and Musa Manarov, call sign "Okeans", was the EVA on February 26 to install a new solar panel section, with the period to the end of March also seeing the Mir complex receive two Progress automated cargo spacecraft.

If all goes to plan the two men will become the first to spend a full year in space. They were launched on December 21, 1987, relieving Yuri Romanenko and Alexander Alexandrov both of whom spent some time after the flight convalescing in the Caucusus spa town of Kislovodsk, with their families.

Romanenko and Alexandrov, together with Laveikin*, were interviewed and pictured in late January during their stay at Caucusus, with the Soviets eager to counter some sensational western reports that Romanenko was a physical and mental wreck.

During a Moscow press conference on January 20, the cosmonaut had given journalists some insights into his stay on Mir. TV and still pictures of him published later that month showed him to be in good health.

Meanwhile, in space, Titov and Manarov have been preparing for the June 7 launch of the Soviet/Bulgarian short-stay crew and a possible EVA to repair the UK's TTM shadow mask X-ray telescope on Kvant which is malfunctioning.

Work with the module during early 1988 has concentrated on studies of supernova 1987A and other targets. The first X-rays detected by Mir's telescope suite from SN 1987A were on August 10, 1987. The flux then increased for two months when, on about October 15, the radiation began abating before intensifying in November to the point where, in early February they were 50 per cent above the August levels. The Soviets say this is related to periodic "holes" in the outer expanding shell of the supernova.

Additionally, the men spent a week in early February calibrating the telescopes with the aid of ground controllers, using the Crab Nebula as the standard source for the calibration.

Soviet/Bulgarian flight brought forward to early June to avoid "full Moon".

Progress 34 and Mir

The Soviets launched Progress 34 towards Mir at 2252 (all times GMT) on January 20. It docked with the port at the back of Kvant at 0009 on February 23, delivering some 2 tonnes of fuel, food, water, equipment and mail for the men.

Amongst experiments being conducted during the period of the Progress flight were regular smeltings with the Korund furnace to produce improved semi-conductor crystals, experiments with the Pion unit to study thermocapilliary actions in weightlessness, the ERI experiment to test methods of depositing galvanic coatings in weightlessness, and the Maria and Glazar astrophysics experiments. The Maria experiment involved use of a spectrometer to study the flows of high-energy particles around the Earth.

The Glazar UV telescope was mounted on Kvant and is conducting a survey of bright galaxies and stellar associations at UV wavelengths of 1640 angstroms. The programme uses time exposure photography, up to eight minutes in duration, of stellar regions which allows stars to magnitude 17 to be photographed in a 1.3 degree field of view. The UV film is changed periodically through a small airlock in Kvant. The Soviets say that a second Glazar telescope will be installed in another module which will be docked to a radial port of Mir in about two years. This will allow the two telescopes to have a 90 degree separation geometry.

A Walk in Space

On February 12, the Soviets revealed that the staff of the Kaliningrad control centre were briefing Titov and Manarov on techniques they had practiced on Earth in preparation for an EVA at the end of the month. The next two weeks were often to contain references to the upcoming EVA.

The cosmonauts had practiced the EVA in the water tank at Star Town and a picture was released after their launch showing them during that simulation. Experiments that the men had prepared to conduct were, from February 17, temporarily curtailed due to EVA preparations.

On February 23 the men transferred their EVA space suits to the airlock of the base unit and over the next two days tested them out in preparation. The hatch of one of the radial docking units on Mir's front docking unit was opened at 0930 on February 26, over the Pacific east of Australia and thus outside of the radio contact zone of the USSR.

The men's first task was to transfer their equipment from the airlock to the working zone next to the set of solar panels erected by Romanenko and Laveikin in June 1987. The task of the EVA was to replace one of the two lower panels of the two-tier solar array with a new set of panels which contained samples of photoelectric transducers of semi-conductors with improved energy properties. Various types of photoelements are to be tested with the aim of enhancing the effectiveness and durability of solar batteries, the Soviets said.

The new panel has eight small cells. Six will provide energy to the batteries whilst two others are being used as laboratory specimens not providing any electricity to the station but sending data to Earth *via* telemetric channels. The other six cells are made from an unspecified material which not only compensates for the absence of the other two but also provides a power increase to the station of about 20 per cent.

The Soviets later revealed that they are planning to switch the power supply of stations from the present 27 volts. This will enable great savings (in

**Soviet officials have revealed that the anomoly in Laveikin's heart rhythm which forced his early return in Soyuz TM-2 was first detected after the April 11, EVA. The Soviets claimed at the time that further EVA's, planned for early May were postponed for reasons of scheduling. Laveikin's condition would seem to account for the postponement. When the cosmonaut completed his second EVA on June 11, the irregularities with his extrasystoles resumed and doctors decided to replace him with Alexandrov. They have since passed the cosmonaut fit for future flights.*

the order of tonnes) in the weight of cables alone on future stations.

Titov and Manarov were seen on TV during the EVA winding down the lower set of the solar panels, then replacing one with the new set and winding it back to full deployed length. They connected cables to the electrical system.

Before returning to Mir they took video shots of the side of the station, concentrating on the deployed elements of the station and their Soyuz TM-4 spacecraft, for study on Earth. They then placed a number of unspecified science instruments on the skin of Mir to be exposed to raw space for a long period.

During periods of orbital night-time the cosmonauts used small spotlights attached to their helmets to illuminate their work. They returned to Mir's interior after an EVA which had lasted for 4 hours 25 minutes. Once in the station the men had a brief rest before undergoing a medical check.

"Smell" Bothers Cosmonauts

At 0340 on March 2 the Progress 34 cargo craft, which had refuelled the station's combined propulsion system in February, was undocked. At an unspecified time on March 4 the engine of the cargo spacecraft was ignited and the craft was burned up in the upper layers of the atmosphere, as planned.

During early March the men continued their work with the Pion, Maria and other experiments. They were also reported to be using a mirror-beam furnace which used two lamps to concentrate heat of up to 1,000 degrees centigrade onto a small area for smelting purposes.

In mid-March the cosmonauts conducted a series of Earth observations which included studies of snow and glaciers in the Pamir and Tien-Shan mountains as part of a study for understanding the problem of irrigation in Central Asia. Observations were also made with the Kvant telescopes.

A Soviet report spoke of the work having "ups and downs" but said that on the whole the cosmonauts were keeping to their work programme. The men were said to be sleeping well but were bothered by dust and the "smell" of the complex.

On March 17 the cosmonauts were reported to be conducting a new experiment, called Akustika, designed to study the effects of the background noise of instruments, such as fans, on the living quarters.

Progress 35 in Orbit

The Indian IRS-1A remote sensing spacecraft was launched by the Soviets on March 17, from a snow-swept Baikonur Cosmodrome. A BBC TV reporter covering the launch was also shown inside the assembly building, where the Soyuz rockets are assembled, and allowed to see the next Progress spacecraft being readied for launch. He was told that the launch would be on March 24.

On March 21 Manarov celebrated his 37th birthday and "since there were no urgent matters", the two men were allowed the day off! It was also reported that a new telefax system had been installed in the station and that it was being tested.

At 2105 on March 23 (March 24 at Baikonur) Progress 35 was duly launched and two days later at 2222 docked with the rear docking unit of Kvant.

In addition to the normal supplies of fuel, equipment and mail, the craft brought some 400 kg of food which included fresh vegetables and fruit. The crew unloaded Progress over the next few days.

The men were sleeping well but reported being bothered by the 'smell' of the complex.

A medical report was issued on March 29 which said that Titov's pulse rate was 67 beats/min and his blood pressure 110/70. Manarov's were 73 and 115/70 respectively. Earlier the Soviets had said that Titov had lost 1.5 kg in weight whilst Manarov had actually gained 3.5 kg!

The first week of April saw more observations with Kvant, more medical tests, more Earth observations, atmosphere studies with the EFO-1 photometer and smelting tests with a Czechoslovakian-made Kristallisator unit which is studying the structure and formation of crystals in space.

On April 7 it was reported that the men were installing new equipment which would help increase the potential for communications between the Earth and Mir.

Subsequently, it was reported that the cosmonauts were seeming to slip behind in their work schedule.

Future Flights

News that the Soviet/Bulgarian flight is to be brought forward to June 7 from its original date of June 21 was given on March 29 by Prof. B. Bonev, the head of the Space Research Institute of the Bulgarian Academy of Sciences.

The reason for the switch was the necessity of a dark sky for the astronomical experiments planned for the Rozhen astronomical complex – from June 21 onwards the full moon will lighten the night sky.

The crew for the mission – Soviets Anatoli Solovyov and Viktor Savinykh and Bulgarian Alexander Alexandrov – are to conduct 40 experiments under the overall codename of Shipka. Nine sets of apparatus, produced with Bulgarian participation, were due to be flown to Mir on a Progress craft in early May. The study programme involves areas of space physics and materials studies, remote sensing of Earth, space biology and medicine.

Rozhen is described as an electron optics system of a new generation which will observe stars, galaxies, etc., and will digitally process the results.

Other experiments will involve the Lyulin system, a microprocessor for psychological and physiological analysis of the cosmonauts' reactions, and the Pleven system which will be used to perform 15 psychological tests.

During this international flight, the smelting facilities on Mir will be used to produce a wolfram/aluminium alloy in the Voal experiment.

The Bulgarians, who claim to be the third largest producer of space food in the world after the USSR and the USA, will also supply a joint menu.

Training with the equipment for the flight by the two flight crews started in January 1988. It is also expected that the men will take into orbit small personal computers to Mir to process the results of their experiments instead of waiting for them to be analysed on Earth after the end of the flight.

Savinykh has already said that the flight programme is "a bit too much for seven days", which was the originally planned duration of the joint mission.

Afgan Flight Brought Forward Too

The Soviets have also announced that they are to fly the cosmonaut from Afganistan, either Col. Mohammad Dauran or Capt. Abdol Ahad, in August 1988 rather than the earlier expected date of 1989. The early date may be the result of the Soviet planned withdrawal from that country, and the need to have in power the government which agreed to the flight. Both men have been paired with Soviet crews but these had not been announced at the time of writing.

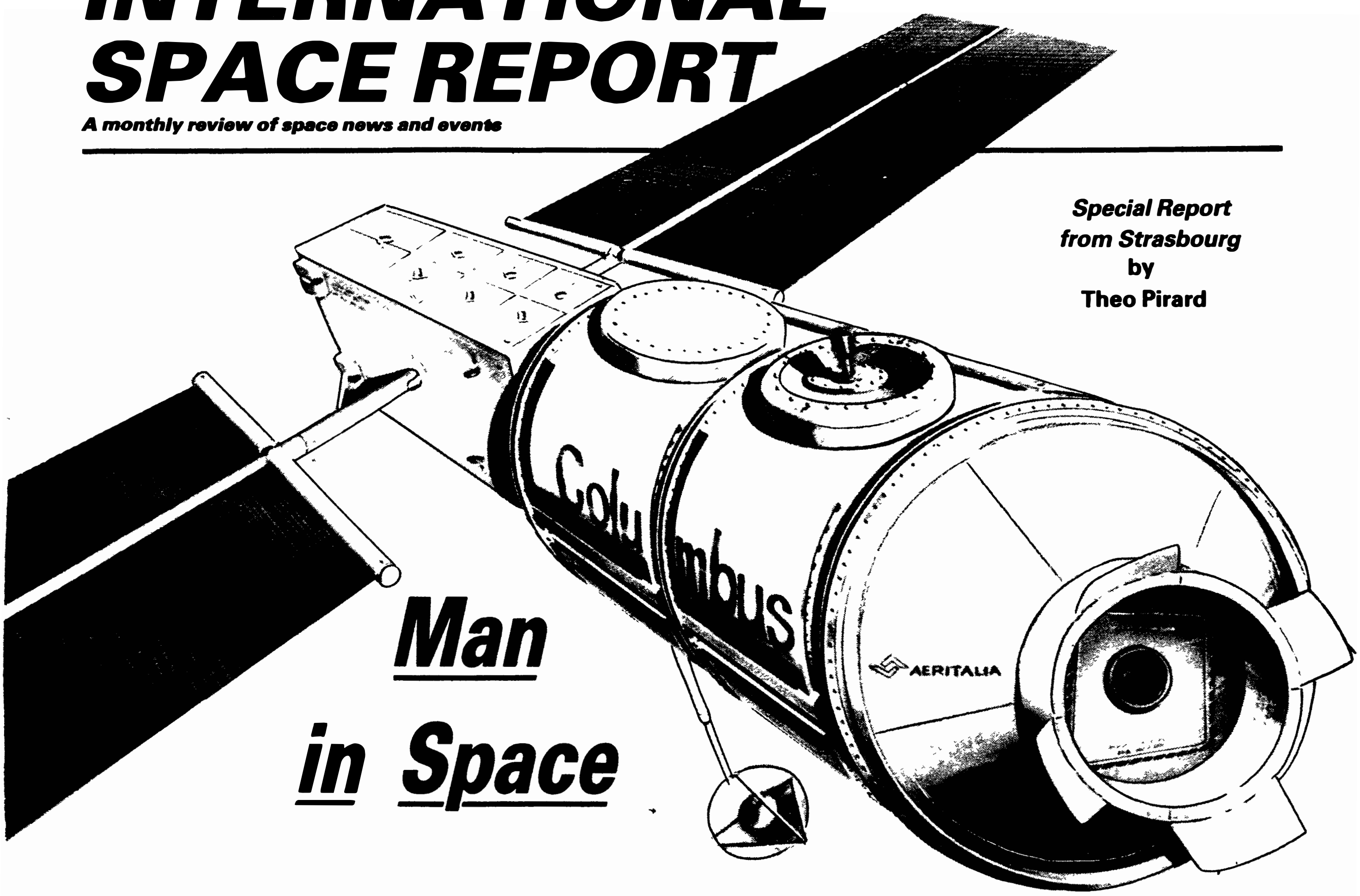
French Mission

Finally, the planned Soviet/French flight to Mir for a joint flight time of 30 days is still planned for late November 1988. It is currently anticipated that the Soviet commander will be Alexander Volkov and the French cosmonaut, Jean-Loup Cretien, but the Soviet Flight Engineer is currently unnamed (see the previous Volkov interview for more on this).

Reports coming from the Soviets that both the Bulgarian and French cosmonauts will take part in EVA's with special jet bicycles have, the Soviets now say, been greatly exagerated. The bicycle referred to is the stationary veloergometer on Mir! The Bulgarian will not make a space walk but Cretien will perform an EVA during his mission to erect a special antenna on the exterior of the complex (see p.227).

INTERNATIONAL SPACE REPORT

A monthly review of space news and events



Special Report from Strasbourg by Theo Pirard

Europe Goes for Autonomy

The European city of Strasbourg played host at the end of April to the first International Symposium on Europe in space "The Manned Space System". Some 750 people, including delegates from USA, China and Japan attended this technological and industrial meeting organised jointly by ESA (European Space Agency), CNES (Centre National d'Etudes Spatiales), BMFT (BudesMinisterium für Forschung und Technologie) and MRST (Ministerio per la Ricerca Scientifica e Technologica).

This family celebration of the 2000 anniversary of Strasbourg's foundation was an excellent opportunity to appreciate new technological advances and original R & D operations for the European space infrastructure of the year 2000.

International cooperation based on an enthusiastic effort to be supported by governmental funding will be essential to get in orbit both the Columbus space station and Hermes spaceplane by the end of this century. Three conditions will be required to develop and operate within the next 10 years to meet these ambitious objectives. These are:

1. Enthusiasm of ESA partners – mainly France, Germany and Italy – to solve the technological unknowns of Hermes concepts and Columbus operations, to harmonise their respective requirements for a successful European manned space system, to consolidate their national industries and research capabilities in the frame of the new technologies (tests, computers, communications, data processing, etc).

2. Governmental support to finance the projected budgets for Ariane 5, Columbus and Hermes programmes, to accept the unavoidable growths of expenses due to the development of advanced systems and manned reliable elements, to promote and manage the operations of this autonomous presence of Europe in space; ground support equipment, with user support centres, has to complete the European infrastructure in orbit.

3. International harmonious cooperation between ESA member states, also between Europe and USA, between Europe and Asian countries (especially China, which, as a developing country, needs technological assistance for its autonomy in space). The USSR, USA, Europe, Japan and China have plans for manned space activities with orbital platforms in the year 2000 so why not coordinate for safety and efficiency purposes all these activities through an international effort?

Hermes – More Advanced than the NASA Space Shuttle?

Frederic d'Allest, Director General of CNES, summarised the technological challenges of Hermes design and development.

The main critical challenge for the Hermes transportation system said D'Allest, is the modest dimensions and limited weight of the European manned space plane. Its performance parameters are dictated by the Ariane 5 launch vehicle:

- 5.9 tons in GTO.

- 18 t in LEO (500 km circular, 28°5 inclination), which will be the orbit of Columbus MTFF (Man-Tended Free-Flyer) station.
- 22.8 t in LEO (100 km/500 km, 28°5 inclination), which will be the trajectory of the Hermes spaceplane.

The main objective of Ariane 5 is to reduce the cost of commercial satellite launching, not only to GTO but also in LEO. The hope is to offer an Ariane 5 launch vehicle for the price of the most powerful Ariane 4 model (4 tons in GTO).

Questioned about the technological complexities and performances of the Hermes spaceplane, d'Allest said: "The Soviet Soyuz spacecraft also has limited capabilities but it is flying regularly for maintenance missions. Hermes will guarantee the manned autonomy of Europe in space, but it will be used only when a manned presence is required on an orbital facility. It is not designed to bring back to Earth heavy payloads."

ESA is considering two types of missions for Hermes:

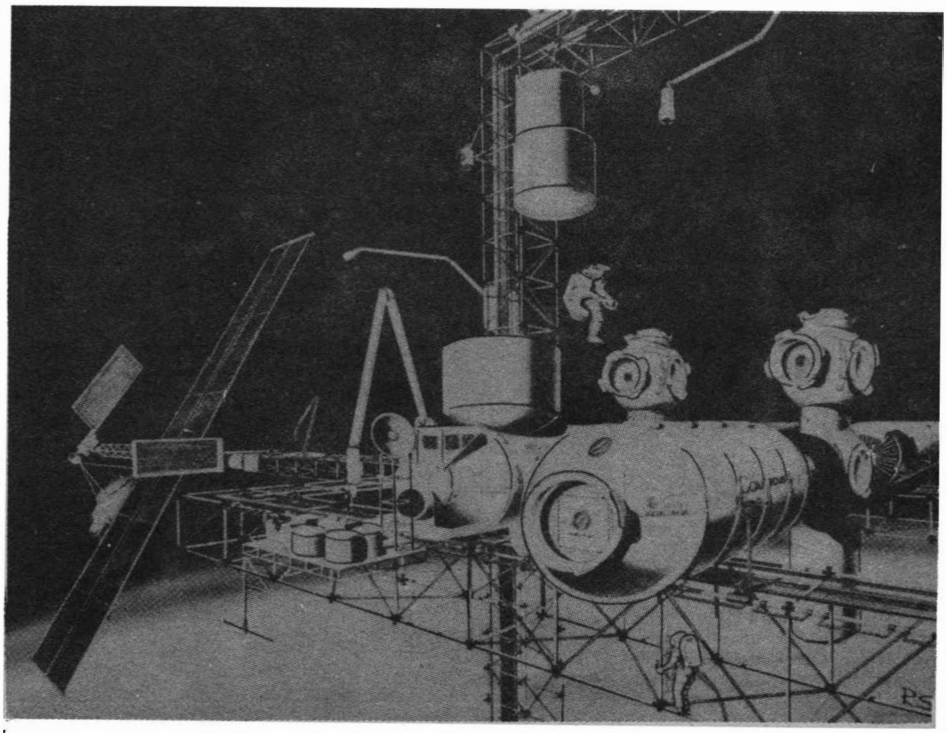
- Primary missions, with servicing of Columbus, or with servicing of Columbus MTFF, or with visit to the Columbus APM fixed on the International Space Station.
- Secondary missions, as an in-orbit technology demonstration vehicle (with onboard experiments), for long-duration flights (up to 28 days), servicing of automatic platforms, visits to the Soviet Mir complex in orbit, as a rescue spacecraft for the US space station (discussions have started with NASA concerning this latter use of Hermes).

In-Orbit and Ground Infrastructures

The entry of Europe into the field of manned space flight means the development of a highly new infrastructure in orbit, with Data Relay Satellites, and a decentralised control network consisting of centres in various parts of Europe (depending on the financial support of each country for the ESA major programmes).

The complexity of this European infrastructure for Columbus and Hermes operations arises from:

- The number of countries requesting investment returns into their respective territories: France will have the Hermes flight control centre, while Germany and Italy will operate Columbus MTFF and Columbus APM control centres respectively.
- The large number of cooperating nations.
- The number of in-orbit systems, including the three Columbus elements, the Hermes spaceplane, the Data Relay Satellites (two located at 44°W, 61°E) and Ariane 5 missions.



International space station in operation. *Aeritalia*

A decentralised complex of ground facilities has been approved by the ESA Council to train Hermes pilots and mission specialists, and Columbus payload specialists. Training facilities in Europe will consist of a Crew Training Centre for ESA astronauts with headquarters at the DFVLR Cologne airport facilities (Porz-Wahn), a Pilot Training Facility near Brussels airport, Hermes familiarisation mock-ups at Toulouse manufacturing facility, EVA training facilities near Marseille (COMEX), APM engineering support facilities at Torino (Aeritalia), HERA (Hermes robot arm) training facility at ESTEC (Noordwijk), and rescue training facilities at Trondheim (Norway).

To operate missions involving Ariane 5, Columbus and Hermes prime facilities will be located at ESOC (Darmstadt) for the Central Mission Control Centre; Centre Spatial de Toulouse for the Hermes Flight Control Centre; at Torino for the Columbus APM Centre; at Oberpfaffenhofen (German Space Operations Centre) for the Columbus MTFF Control Centre, for the Columbus APM Payload Operations & Coordination Centre; in Germany, for the Columbus MTFF Centre; in the United Kingdom, for the Columbus PPF (Polar Platform) Centre; in Italy, for the Data Relay Satellite Operations Control Centre, with prime TT & C stations. It will also include a minimum of two DRS-Central Earth terminals (CET) connected via a wide-area network, located at Aussaguel in France, and Weilheim in Germany.

Hermes Escape System: To Be Or Not To Be?

In addition to its small dimensions and weight limits complexity is added to the Hermes spaceplane by the need for a crew escape module.

This ejectable cabin has a volume of 7 m^3 and a total weight of some 3 tons. It will be useable only during the two minutes of Ariane 5 flight when the two solid strap-on boosters are functioning.

Bernard Deloffre, Hermes Programme Director at Aerospatiale, stated: "We designed the escape module to follow safety requirements made by astronauts in Europe. Now the result of our studies is known, we are criticised for this solution. If it is established that this solution will handicap severely the reliability and efficiency of Hermes, we will abandon it. But it is better to design Hermes with a possible escape system than to follow the NASA strategy with the Space Shuttle... it now looks impossible to modify the Space Shuttle cabin into an ejectable module."

Justifying the strategy of the Hermes escape system, d'Allest, Director General of CNES, says: "This ejectable cabin clearly represents a technological challenge for the European aerospace industry; it will be a first in the world and we are not allowed to economise on such a system if we want to fly with reasonable risks."

Mobile Satellite Services in Europe

ESA is encouraging the use of satellites and the development of Earth terminals for mobile multi-purpose services as an essential part of its Telecommunications Programme until the year 2001. In cooperation with Inmarsat, through experiments with the Marecs space segment, the Prosat demonstration programme is now in its Phase 2.

For the 1990's, ESA is proposing the PSDE (Payload and Spacecraft Development and Experiments) programme to test the technology of spot beams (ARAMIS) and to establish an early European regional system (LAMEX). Eutelsat is studying the possibility of incorporating a mobile communications payload aboard its third-generation satellites (Eutelsat III) of the late 1990's, and the French space agency CNES is intensively working on the establishment of the "private" Locstar system for a pan-European radio-determination satellite service in the air, on land and at sea, with short electronic messages.

ESA's Prosat Phase I programme was successful in defining, through satellite and simulation tests, the technical characteristics and performance of new mobile terminals. The current Phase II is performing long-term evaluations of the prototypes developed under the first Phase and is collecting and evaluating data to define an advanced payload with regenerative repeaters and multibeam antenna.

For the next decade, as a logical continuation for the Olympus communications technology programme, ESA is implementing the Payload and Spacecraft Development and Experimentation (PSDE) spacecraft. Two experimental satellites are planned for launch in the 1992-1995 time period into geostationary and high-inclined orbits. Among candidate experimental payloads under consideration for these technological missions, two concern specifically mobile satellite services:

- Aramis, an advanced payload for aeronautical/maritime mobile communication, will prepare the way for the third generation of Inmarsat spacecraft with the demonstration of spot beam technology with frequency re-use: at L-band, a single antenna can be used to generate, transmit and receive a global beam (EIRP of up to 39 dBW) and, typically, 12 fixed spot beams (EIRP of about 45 dBW). ESA is proposing the PSDE-Aramis concept for operational services within the Inmarsat system to demonstrate and promote these new features.
- The Lamex (Land Mobile Experimental) payload will establish a first regional system for land-mobile services in Europe and aeronautical links over the North Atlantic Area. It will demonstrate the performance of phased array technology with frequency re-use and it will continue Prosat services for low G/T terminals, and telephony services for enhanced terminals.

British industry, which is already involved in the Marecs and Inmarsat 2 spacecraft, is particularly interested in the development of Aramis and Lamex payloads. Marconi Space is studying the Aramis concept (***Spaceflight***, April 1988, p.141) while British Aerospace is working on a LAMEX concept.

The French Satel Conseil consultants have evaluated the potential market in Europe for a satellite-assisted private network system for mobile communications. A low estimate gives 1,500 potential subscribers requiring 2,500 frequency channels, while a high estimate that considers access by smaller hauliers for shared-time operation of a joint frequency comes up with 7,000 required frequency channels. In the medium case, depending on the competition from cellular radio networks, the European market would consist of 2,800 potential subscribers.

Pilot Training Facility

The ESA Council accepted on March 17, the Belgian proposal for the establishment of the Hermes Pilot Training Facility at Brussels airport. ESA will invest some 6 billion Belgian Francs in the development of its new establishment, which will provide the training simulation systems and the Hermes Training Aircraft (HTA) which will use a modified business jet simulating the Hermes environment. Belgian national airline Sabena will play an important role: Sabena has well-known know-how in simulation systems and training operations.

The Belgian SPO (Science Policy Office) will be responsible for the exact location of the facility and for its building. French CNES will be responsible for the simulation systems and training operations for ESA, the latter being in charge of management, as owner of the general facility.

The Hermes Pilot Training Facility has to be operational to train up to eight Hermes pilots by 1994. The nominal duration for the training of ESA astronauts will be four years.

Michel Praet, Space Research and Technology manager at SPO, has outlined the reasons for Belgium being happy to welcome the Hermes Pilot Training Facility to Brussels. In the first place Belgium is strongly supporting Europe in space, becoming the fourth ESA member State ion order of European space participation. Secondly space simulation systems represent an area of specialist know-how for the Belgian Sabena and electronics industry. Thirdly, Belgium would like to become a European centre for simulation systems. This would reinforce the European role of Brussels. Fourthly, the Hermes facility at Brusels will be a major investment for Belgium. It is expected that this establishment will grow and see additional ESA facilities established at Brussels. Belgium also hopes that the role of the ESA Redu Station, located in the Belgian Ardennes, will be increased with the advent of new communications satellites (PSDE, DRS, AOTS). Redu is used as the control centre for the ECS-Eutelsat spacecraft.

Hermes Cabin Criticised

Officially the Hermes project is facing some temporary problems that are to be expected with any design finalisation...

But the ejectable Hermes cabin has come in for strong criticism from German astronauts and a report of the Association of European Astronauts. They say that the use of an ejectable cabin is not the right way to tackle the problem: it will add weight to the Hermes spaceplane and will reduce its performance in orbit. It appears that the criticism of the astronauts is only the tip of the ice-berg and that the design of Hermes is seriously in trouble.

At Toulouse, CNES, Aerospatiale and ESA are actively analysing how to realise this manned reusable spacecraft within a time-scale of 10 years and a weight limit of 21 tons (3 ton payload and three astronaut crew included) and equipped with a sophisticated 3-ton cabin. At ESTEC, Noordwijk, the ESA engineering team is helping the Toulouse team to review possible solutions. All the time it is appearing more certain that Hermes will not fly during this century and that its development will be more expensive because of the high complexity involved and a serious lack of European know-how in manned space flight. Will Hermes fly on April 12, 2001 to celebrate the 40th anniversary of first manned space flight (with cosmonaut Yuri Gagarin) and the 20th anniversary of Space Shuttle mission No.1? This possibility now appears to be a vanishing hope. *Theo Pirard*

UK Leads Bid For New Euro Rocket

A new European satellite launcher called LittLeo, conceived by the British consultancy GTS, is now moving into its next phase to establish the detailed planning elements for its subsequent development programme.

General Technology Systems Limited, following an encouraging market survey which it undertook in 1987, is to lead a European team into the next phase of a programme to develop LittLEO, a little launch vehicle for low-Earth orbit (LEO) operations.

This phase, which will extend over the next few months, will establish all the detailed planning elements on which subsequently, a full development of the programme could be committed. Andøya, in Northern Norway, site of a successful sounding rocket range for over 25 years, is to be the first operational base for this satellite launcher, which is intended to put payloads of 300 kg to 500 kg into polar orbits at 300 km and higher altitudes.

The proposed launch vehicle will not compete with Ariane or any of the other large launchers capable of putting much bigger payloads into geostationary orbit. LittLEO has been conceived to provide a European means to close the gap at the lower end of the launcher market.

2165

SATELLITE DIGEST — 213

Robert D. Christy

Continued from the May 1988 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

USA 30, 1988-8A, 18847
Launched: 2208*, 8 February 1988 from Vandenberg AFB by Delta 3910.
Spacecraft data: not available.
Mission: Part of the SDI (Strategic Defense Initiative) program, launched to gain experience of space-based missile tracking. Fourteen sub-satellites were released to act as dummy warheads.
Orbit: 221 x 338 km, 89.92 min, 28.59 deg.

COSMOS 1917-1919, 1988-9A to C, 18857-18859?
Launched: 0023, 17 February 1988 from Tyuratam by D-1-e.
Spacecraft data: not available
Mission: Intended launch of a triple payload of GLONASS (Global Navigation Satellite System) vehicles. A problem with the launcher's final stage prevented then reaching the desired 19000 km circular orbit.
Orbit: 141 x 315 km, 89.07 min, 64.81 deg.

COSMOS 1920, 1988-10A, 18860
Launched: 0950, 18 February 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 14 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 323 x 341 km, 91.24 min, 82.60 deg.

COSMOS 1927, 1988-11A, 18875
Launched: 0800, 19 February 1988 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 346 x 415 km, 92.20 min, 70.02 deg.

SAKURA 3A, 1988-12A, 18877
Launched: 1005, 19 February 1988 from Tanegashima by H-1.
Spacecraft data: Spin-stabilised cylinder, approx 3 m long and 2.2 m diameter, with mass 1100 kg fully fuelled.
Mission: Improved Japanese domestic communications satellite.
Orbit: geosynchronous above 130 deg east longitude.

COSMOS 1922, 1988-13A, 18881
Launched: 0932, 26 February 1988 from Plesetsk by A-2-e.
Spacecraft data: Probably similar to the Molniya satellites, in which case it has a cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries sensors and a solar panel array set in a plane at right angles to the main axis of the body. Stabilisation is probably by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Part of the USSR's ballistic missile early warning system.
Orbit: Initially 614 x 39300 km, 708.86 min, 62.92 deg, then raised to 615 x 39744 km, 717.87 min, 62.92 deg to ensure daily repeats of the ground track.

CHINA 22, 1988-14A, 18922
Launched: 1241*, 7 March 1988 from Xichang by Long March 3.
Spacecraft data: Spin-stabilised, cylindrical body, approx 2 m long and 2 m diameter with mass around 500 kg.
Mission: Chinese domestic communications satellite.
Orbit: geosynchronous above 87.5 deg east longitude.

COSMOS 1923, 1988-15A, 18931
Launched: 1030, 10 March 1988 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 12 days.
Orbit: 227 x 349 km, 90.32 min, 72.85 deg.

COSMOS 1924-1931, 1988-16A to H, 18937-18944
Launched: 1220, 11 March 1988 from Plesetsk by C-1.
Spacecraft data: Each satellite is probably spheroidal in shape, about 1 m long and 0.6 m diameter, and with mass approx 40 kg.
Mission: Single launch of eight satellites to provide tactical, point to point communications for troops or units in the field.
Orbits: 1399 x 1461 km, 114.48 min, 74.01 deg (lowest), 1460 x 1516 km, 115.76 min, 74.01 deg (highest).

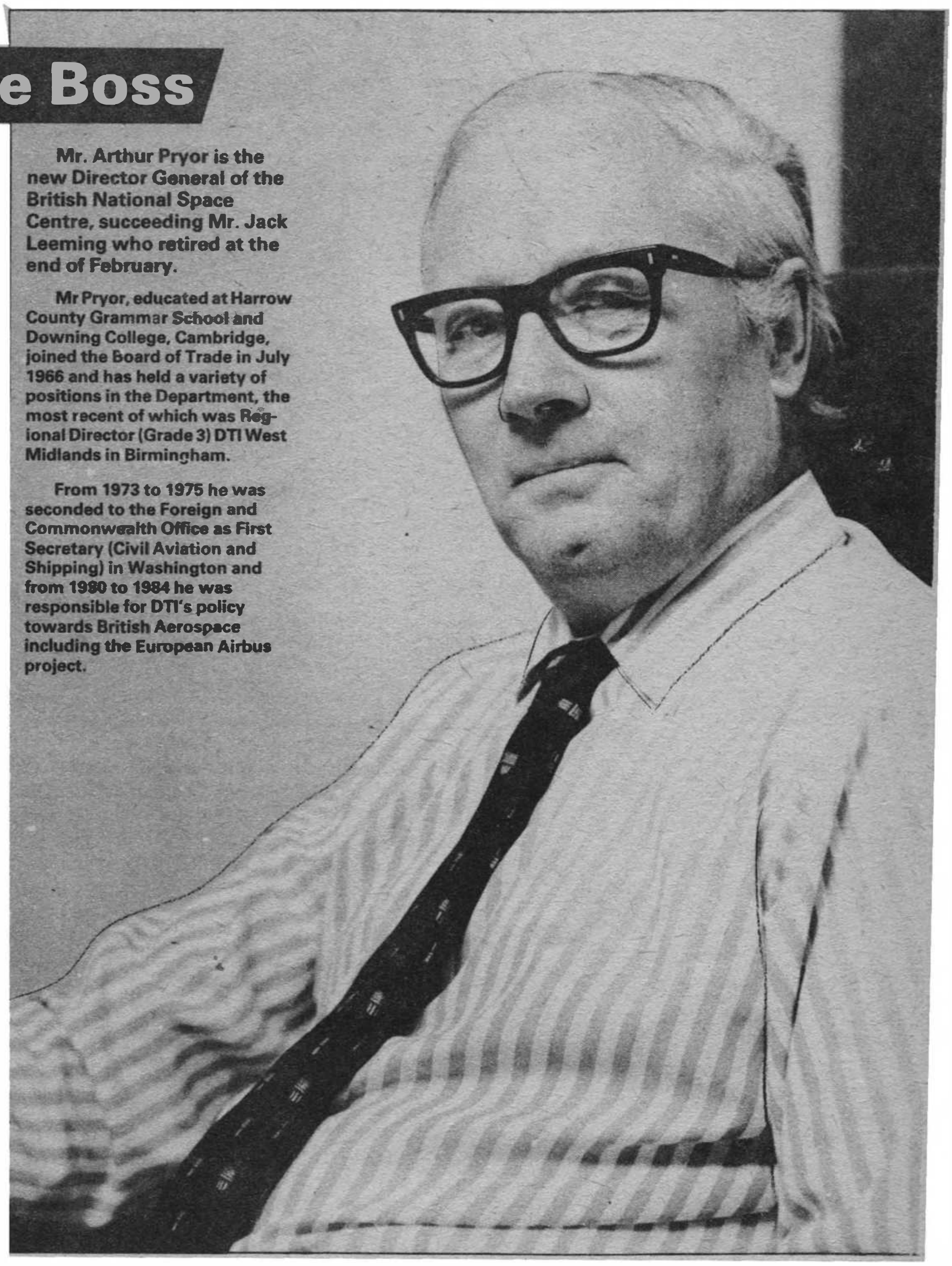
MOLNIYA-1 (71), 1988-17A, 18946
Launched: 0649, 11 March 1988 from Tyuratam, USSR by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 455 x 38977 km, 699.16 min, 63.00 deg, then raised to 458 x 39879 km, 717.42 min, 63.05 deg to ensure daily repeats of the ground track.

SPACENET 3, 1988-18A, 18951
Launched: 2328, 11 March 1988 from Kourou by Ariane 3 (V-21).
Spacecraft data: Box-shaped body, 1.6 x 1.3 x 1 m with 14 m span solar array. The mass (empty) is 710 kg.
Mission: US domestic communications satellite.
Orbit: geosynchronous above 87 deg west longitude.

TELECOM 1C, 1988-18A, 18951
Launched: 2328, 11 March 1988 from Kourou by Ariane 3 (V-21).
Spacecraft data: Hexagonal prism-shaped body approx 2 m across and 3 m tall, with a 16 m span solar array and mass 690 kg (empty).
Mission: French, combined civil and military communications satellite.
Orbit: geosynchronous above 5 degrees east longitude.

INTERNATIONAL SPACE REPORT

New UK Space Boss



Mr. Arthur Pryor is the new Director General of the British National Space Centre, succeeding Mr. Jack Leeming who retired at the end of February.

Mr Pryor, educated at Harrow County Grammar School and Downing College, Cambridge, joined the Board of Trade in July 1966 and has held a variety of positions in the Department, the most recent of which was Regional Director (Grade 3) DTI West Midlands in Birmingham.

From 1973 to 1975 he was seconded to the Foreign and Commonwealth Office as First Secretary (Civil Aviation and Shipping) in Washington and from 1980 to 1984 he was responsible for DTI's policy towards British Aerospace including the European Airbus project.

British Support for Columbus

Britain is to seek a major role in constructing the Columbus polar platform – part of Europe's contribution to the international space station – following an eleventh hour decision to take part in the project.

Mr. Kenneth Clarke, government minister in the department of trade and industry, announced in mid-April that the UK had decided to reverse its earlier decision not to take part in Columbus.

Mr. Clarke said that Britain will seek a major role in constructing the Columbus polar satellite, which will give UK industry and users the opportunity for commercial exploitation of Earth observation activities, at minimum cost to the taxpayer.

Over ten years the government will be putting £250 m into the project, including associated instrumentation. This will amount to a 5.5 per cent share in ESA's Columbus programme.

Mr. Clarke said that he was delighted that the UK industry would also be providing around £5 m. He claimed the decision to join Columbus was a logical development of the Government's earlier decisions to join ERS-1 and to establish a new £20 million Earth Observation Data Centre at Farnborough.

He expects the project to provide over 2,000 man-years of work in the UK with British Aerospace invloved in satellite construction and other UK companies providing ground facilities for operational control and data processing.

Mr. Clarke said: "I told our partners in the European Space Agency at our meeting in the Hague on November 9, 1987 that I was attracted by the idea of participating in Earth observation but that we would require any projects that we joined to be planned on a cost-effective basis and aimed at the maximum scientific, commercial and industrial benefits for the economies of the participating countries.

"I repeated my interest in Earth observation on February 10, 1988 in answer to a Parliamentary Question and said we were not ready then to join the Columbus programme as first proposed. I am glad to say that the design concept of the Polar Platform element of the Columbus programme has been reviewed as a result of our expressed doubts. As now proposed, it will be a more efficient, more utilitarian and non-serviceable spacecraft, with a substantial cost-saving compared with the concept put forward at The Hague.

"I am pleased to announce that we shall be proposing today to our European Space Agency partners that the UK should take a leading role in the Polar Platform as now designed.

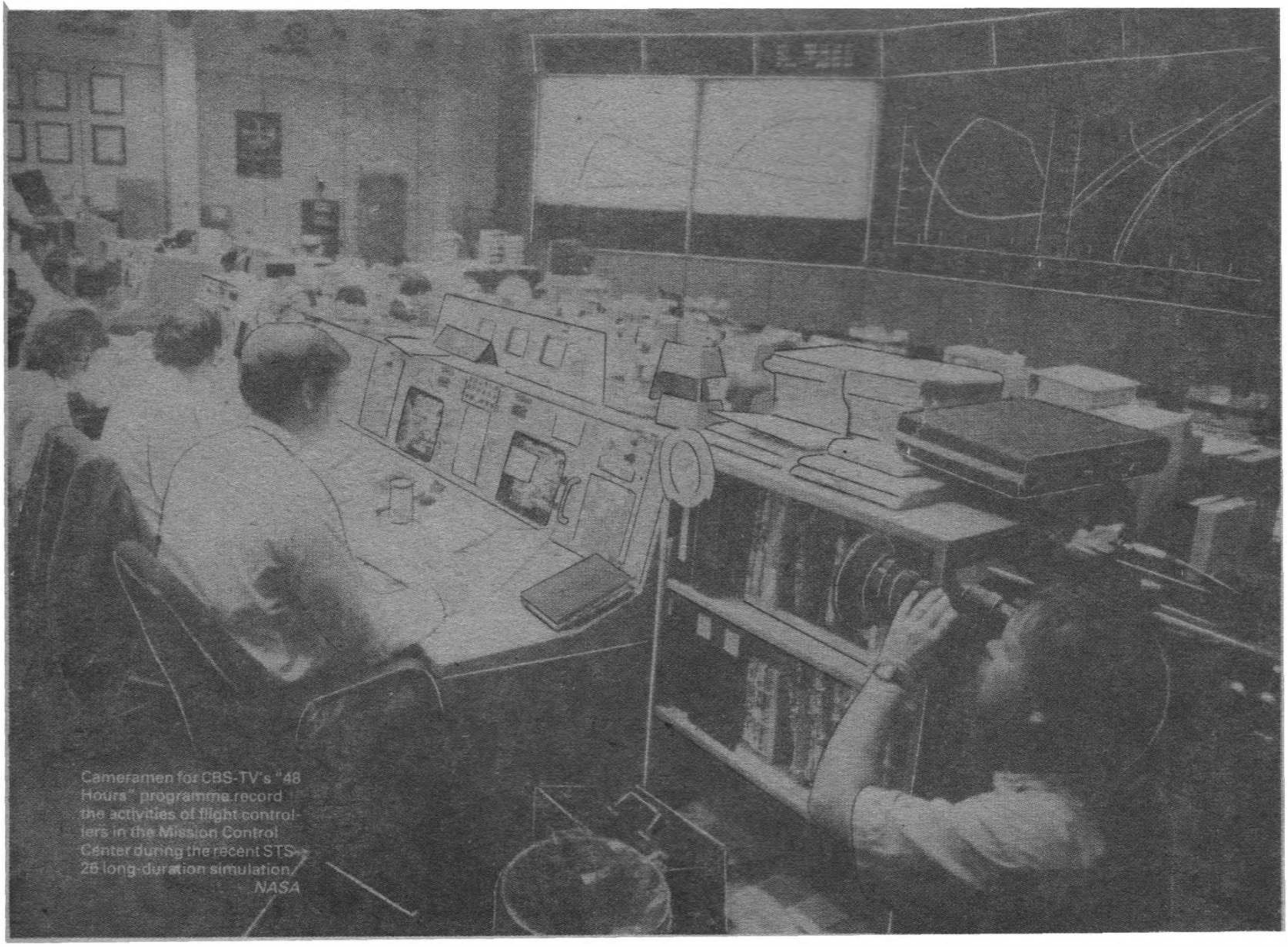
"This represents a sensible next step, based on our consistent policy to support Earth observation, where a commerical market can be developed based on the acquisition and processing of data for sale to end users.

"We joined the ERS-1 project under ESA in March 1982 and ERS-1 is due for launch in 1990. I announced on Febraury 10, 1988 our decision to establish a new Earth Observation Data Centre at Farnborough costing an additional £20 million. We are now set to proceed with the next, major project, the Polar Platform, at a cost of over £250 million over the next ten years.

"Having decided to enter Columbus, the Government will not be entering the Canadian Radarsat project. Radarsat is a good project and we have spent £4.5 million examining it carefully, but it is essentially a one-off project on a smaller scale than Columbus and would not have offered as good a base for commercial exploitation.

"We expect to receive most of the information Radarsat would provide through our membership of ERS-1 and Columbus."

UP-DATE USA



Cameramen for CBS-TV's "48 Hours" programme record the activities of flight controllers in the Mission Control Center during the recent STS-26 long-duration simulation. *NASA*

Mission Simulation Builds Flight Confidence

The lead flight director for the recent STS-26 long-duration simulation says the exercise was a fast paced, comprehensive confidence builder.

"I think it was an excellent sim, said Flight Director Larry Bourgeois. "The simulation folks put together a good script which exercised the MCC (Mission Control Center) as well as the Sunnyvale flight control team responsible for the IUS (Inertial Upper Stage) and the TDRS (Tracking and Data Relay Satellite) flight control team at White Sands.

"It gives us confidence that after the two-year stand-down we still have the expertise and the processes in place, and that the players can work together to accomplish objectives as a team," he said.

Bourgeois said the simulation was fast paced, but that failures were injected in such a way that the flight control teams could evaluate them in depth and respond in detail. Some 80 to 100 malfunctions were inserted during the course of the 32-hour sim.

Bourgeois said the toughest part of the exercise was when a combination of problems delayed simulated deployment of the TDRS. The problems gave the flight control teams in the MCC, Sunnyvale and White Sands a workout in interactive replanning.

Crews responsible for maintaining the MCC and the Shuttle Mission Simulator did an outstanding job of ensuring that they worked and performed during the mission inspite of the many modifications underway during the stand-down, he said.

"We had a good well-balanced exercise of the team," said STS-26 Commander Rick Hauck. "I think it shows that we're well on the way to being fully ready for the STS-26 launch."

• *Computer Simulation Feature. See p.240.*

Tiles for New Orbiter

Deliveries have begun at Lockheed of a new set of lightweight, heat-resistant tiles to protect the aluminium skin of the Space Shuttle orbiter that will replace the Challenger.

Lockheed Missiles & Space Company will supply all materials for the 25,000 tile shipset to protect OV-105, according to programme manager Bruce Burns.

Designed to withstand repetitive re-entry temperatures up to 2,300 degrees F, the tiles are fabricated from 99.7 per cent pure silica fibres.

A black reflective borosilicate-glass coating is applied to all the tiles that will experience the higher temperatures, such as those on the bottom of the fuselage and wings.

Solid Rocket Motor Firing Tests O-rings

The full-duration firing of Qualification Motor-6 (QM-6) at the end of April appears to have been a success, according to initial test results.

The third in a series of five tests of the re-designed Space Shuttle solid rocket motor at Morton Thiokol's Wasatch Facility near Brigham City, Utah, went off without a hitch. The firing lasted two minutes.

The test included two intentional flaws. A "wave defect" was inserted in the surface of the centre field joint's bonded insulation J-seal to test the capture feature O-ring and a small blowhole was created in the polysulfide adhesive of the redesigned case-to-nozzle joint to test the new wiper O-ring.

Test officials said they would continue to analyse the test results, and prepare for the two tests remaining before STS-26, QM-7 and Production Verification Motor-1.

In a related development, NASA announced plans on April 18 to issue a request for proposals in June or July for an Advanced Solid Rocket Motor (ASRM) that would make the Space Shuttle capable of lifting 12,000 more payload pounds and eliminate the need to throttle the main engines during ascent.

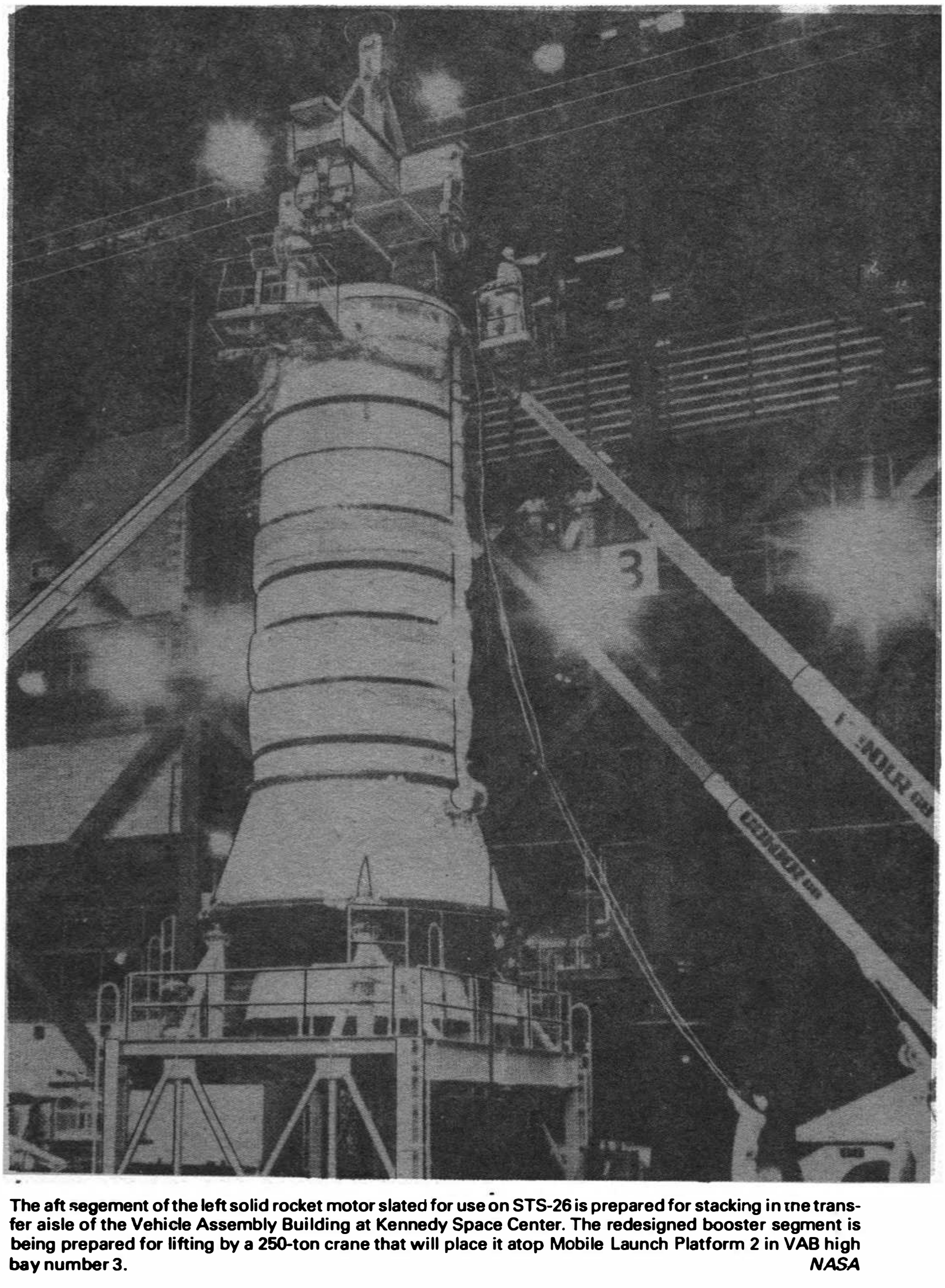
Design, construction and operation of a government-owned test and production facility are part of the request for proposals (RFP). A Site Evaluation Board has been formed to recommend a tentative government site for inclusion in the RFP as a common basis.

The ASRM acquisition plan submitted to Congress contains NASA's strategy for a full and open competition to introduce an ASRM into the Shuttle system. This is expected to substantially improve flight safety design margins, reliability and performance.

The RFP – for ASRM design, development, test and evaluation (DDT&E) – is being scheduled to achieve an earliest launch opportunity in fiscal year 1994.

NASA plans to proceed with a segmented motor design that incorporates substantive design changes to improve the reliability and the design safety margins. In addition, the ASRM ballistic design precludes the necessity for throttling the Space Shuttle main engines during the period of maximum dynamic pressure, which reduces or eliminates about 175 criticality 1/1R failure modes for the Shuttle system.

The ASRM's design goal to provide a 12,000 pound payload increase will equate to an additional 2.4 equivalent Shuttle missions per year (at a rate of 14 missions a year) and will support Space Station deployment and other critical missions.



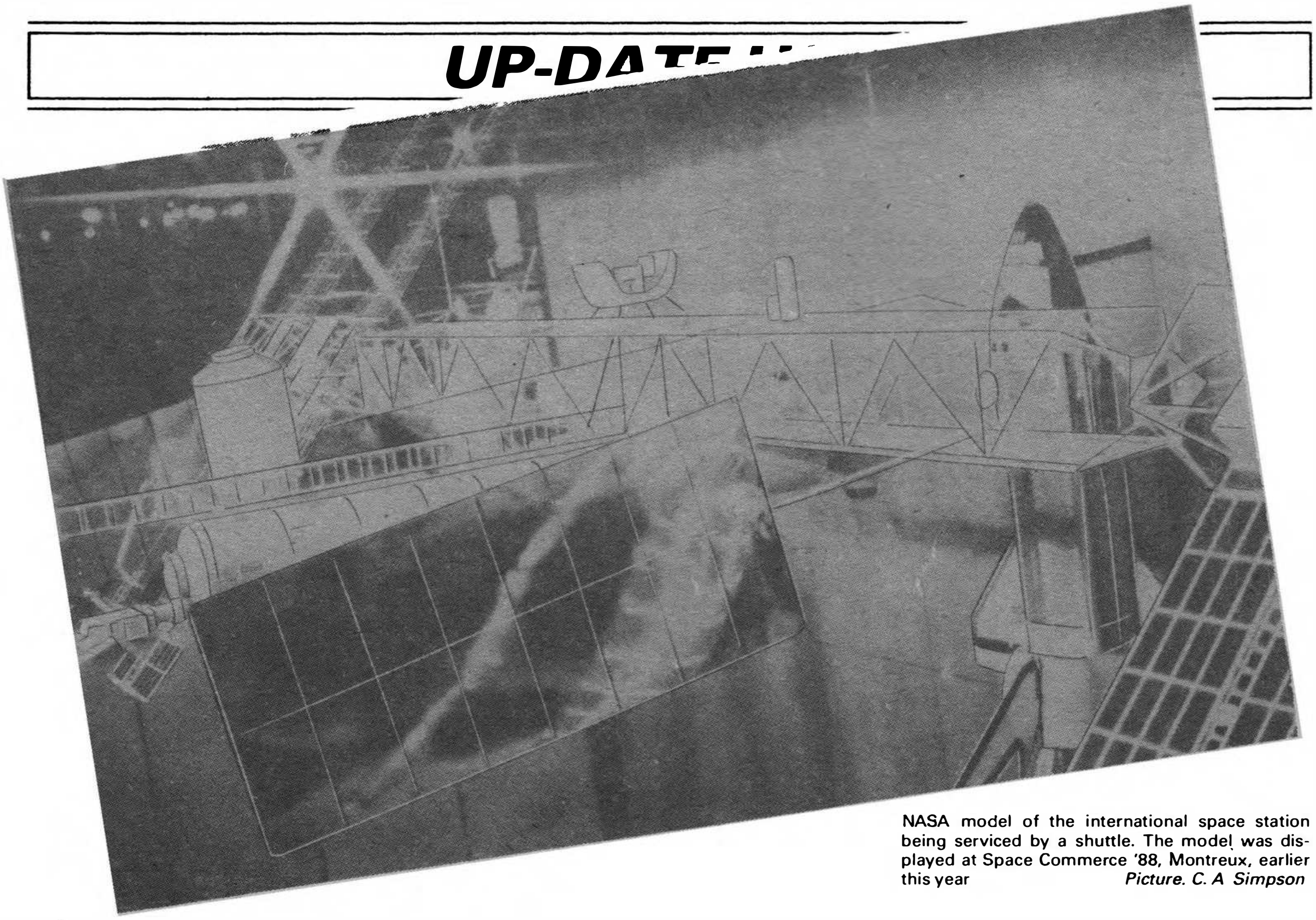
The aft segement of the left solid rocket motor slated for use on STS-26 is prepared for stacking in the transfer aisle of the Vehicle Assembly Building at Kennedy Space Center. The redesigned booster segment is being prepared for lifting by a 250-ton crane that will place it atop Mobile Launch Platform 2 in VAB high bay number 3. *NASA*

To achieve the level of process control and automation needed for high quality and reproducibility, NASA has concluded that a substantially new facility is required.

In keeping with the President Reagan's new space policy encouraging commerical initiatives in space, companies responding to the RFP will be required to propose a private-financing option for the new ASRM facility on a tentative government site. NASA also will solicit optional proposals for a privately owned facility.

The overall ASRM DDT&E cost is estimated at just under $1 billion, including modern tooling and equipment, plus $200-300 million for construction of facilities.

The planned ASRM development is critical to NASA and will provide substantive improvements in flight safety design margins and reliability, achieve full Shuttle payload capability, optimise programme cost, encourage commercial initiatives and promote industry competition.



NASA model of the international space station being serviced by a shuttle. The model was displayed at Space Commerce '88, Montreux, earlier this year *Picture. C. A Simpson*

Budget Crunch To Delay Space Station

Budget restraints will postpone launch of the first Space Station element by a year but man-tended capability can be achieved by late 1995, according to NASA Administrator James C. Fletcher.

Fletcher reported the findings of a "Space Station Program Response to the Fiscal Year 1988-1989 Revised Budgets" on April 12.

"The only sensible way to accommodate the Space Station funding profile inherent in the FY 1988 and 1989 budget reductions is to slip the major programme milestones," Fletcher wrote in a series of letters to congressional appropriations committees.

"I believe that the current Station configuration is the correct one, and that limiting the design would be extremely unwise.... It represents, in my view, the optimal balance between development costs, operations costs and satisfaction of user requirements in a safe Station."

Fletcher said that to achieve earliest possible man-tended capability, the baseline assembly sequence will be changed to provide launch of the pressurised laboratory module on the fourth assembly flight of the Space Shuttle in the last three months of 1995. Such a capability can be provided with minimal cost impacts, and will not delay the permanently manned capability.

The laboratory will be launched with useful capability but will not be fully outfitted until the sixth assembly flight, he said. User outfitting could be quadrupled if the Advanced Solid Rocket Motors were available for lab module launch, he added.

James C. Fletcher.

Before the laboratory can be accommodated, he said, the Station truss structure and basic power, propulsion, guidance and control, and Shuttle docking systems must be placed in orbit on the first three assembly flights.

The full report notes that NASA has directed its four Work Package contractors (Boeing Aerospace, McDonnell Douglas, General Electric and Rocketdyne) – now operating under letter contracts – to constrain hiring of personnel and subcontracting efforts so that they may retain key personnel and add only the staff necessary to accomplish a Program Requirements Review.

Similar constraints have been placed on hiring to support programme-wide engineering and integration analyses through the Program Support Contract with Grumman Aerospace and the Technical and Management Information System and Software Support Environment contracts with Boeing Computer Services and Lockheed Missiles and Space Co., the report states.

"This programme represents a critical element in the Nation's efforts to reinvigorate leadership in manned civil space endeavours," Fletcher wrote.

"The realisation of the full scientific, technological and commercial potential of space requires the attention of men and women living and working in orbit."

Shuttle Crew Escape System Package

A telescoping pole will be the egress method for the Space Shuttle's new crew escape system, and will be incorporated into Discovery prior to STS-26 in August.

The selection of the telescoping pole, over an alternative tractor rocket extraction system, was made at NASA Headquarters by National Space Transportation System Director Arnold Aldrich following a review of system design, test performance and flight hardware status.

"The NASA-contractor team has done a fantastic job in providing both the tractor rocket and telescoping pole systems to support the next Shuttle flight," Aldrich said. "The telescoping pole was selected as it has shown to be safer, simpler to operate, lighter weight and easier to support than the tractor rocket system, while meeting all escape system performance requirements."

The telescoping pole, designed and manufactured at JSC, is made of lightweight aluminum and steel and weighs 241 pounds. It is about 70 pounds lighter than the tractor rockets system. The rockets also have a five-year operational shelf life limitation and additional processing requirements between flights.

Tests conducted in February and March, using a fixed pole extending through a hatch-like opening in a C-141 aircraft, demonstrated that the pole would provide adequate Orbiter clearance (see *Spaceflight*, April 1988, p.199).

The pole housing attaches to the Orbiter's middeck ceiling and is 126.75 inches long. The primary extension is 112.54 inches (arched length), and the end extension is 32.65 inches.

For launch and landing, the unextended pole will be oriented toward the closed crew hatch. During on-orbit operations, the pole will be repositioned toward the middeck lockers and stowed on the ceiling so as not to interfere with flight crew activities.

This decision completes the crew escape system package. Already approved and implemented are the Orbiter primary crew hatch jettison capability and crew support equipment – a partial pressure suit, oxygen equipment, a parachute, a life raft and survival equipment for each crew member.

The escape system provides crew escape capability from the Orbiter during controlled, gliding flight following failures or difficulties during ascent or entry where landing at a suitable landing field cannot be achieved.

International Pact for Rescue System

The USA, the USSR, Canada and France have finalised an inter-governmental agreement committing them to long term support for a satellite system for search and rescue.

The four countries, founding members of the Cospas-Sarsat system, reached agreement in a meeting at the Inmarsat Headquarters in London on April 29. It is hoped that the agreement will be signed within the next few months.

The Cospas-Sarsat system, employing four polar-orbiting satellites fitted with appropriate signal receiving and transmitting equipment, has been operational since 1982 and to date Cospas-Sarsat has been credited with saving over 1,000 lives in various distress incidents around the world.

The new agreement provides a long-term committment to a satellite-based system for search and rescue providing distress alerting and location identification information. It will enable the International Maritime Organisation (IMO) to adopt the Cospas-Sarsat system as part of its Global Maritime Distress and Safety System (GMDSS).

Access to Cospas-Sarsat is available to all countries on a non-discriminatory basis, and free-of-charge for the end user in a distress situation.

Joint Venture To Moon

NASA Administrator James C. Fletcher says the Moon, rather than Mars, may be the best initial destination for possible United States/Soviet Union manned missions.

"Going to the Moon together would give the two leading spacefaring nations in the world an opportunity to build a stable base for further cooperation, which could, one day, lead to a cooperative mission to Mars," Fletcher told participants at the recent National space Symposium in Colorado Springs.

He stressed that any cooperative manned activity should be proceded by a programme of cooperative unmanned activities.

"Flying out to Mars together before building such a foundation could, for several reasons, be less practical," said Fletcher.

In the last several months, a number of parties have advocated a US/USSR manned mission to Mars. Fletcher cited three crucial factors favouring the Moon for an initial cooperative manned mission:

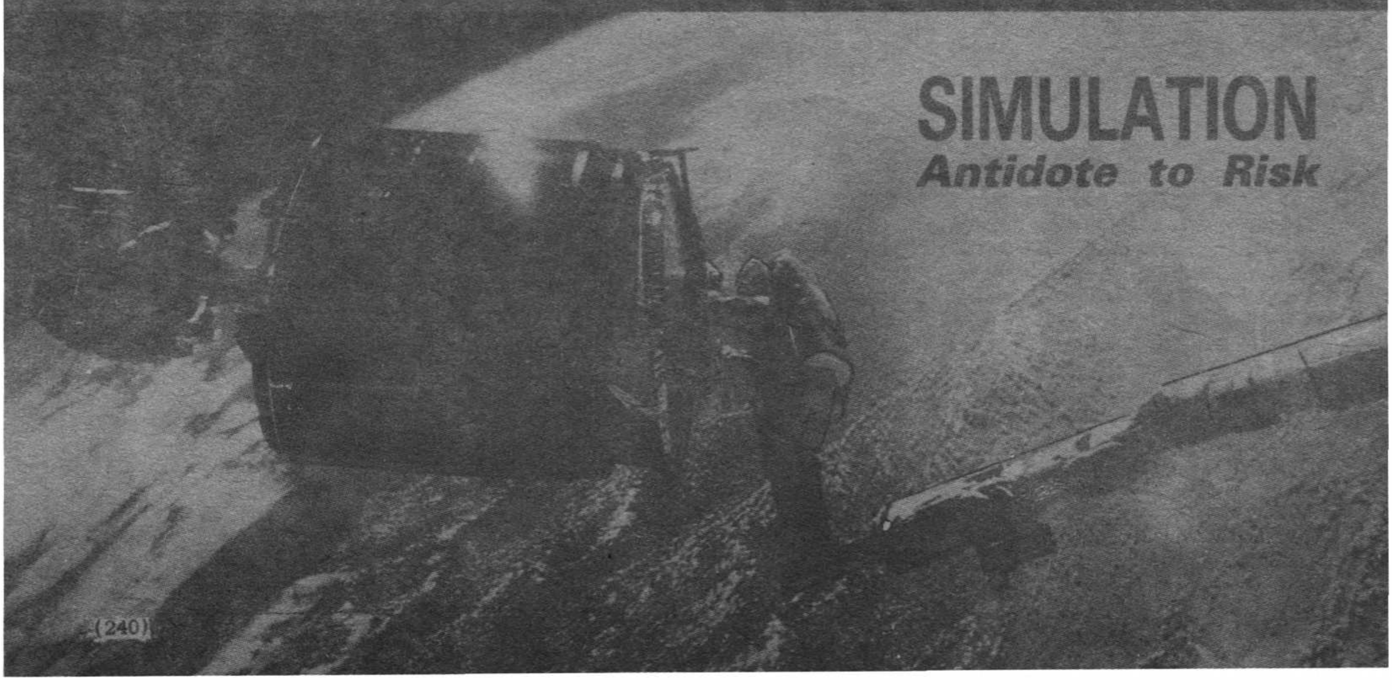
- **Timing – a joint mission to the Moon would involve a relatively short timetable, while a Mars mission "would probably encompass four or five presidential administrations". He said relations between the US and the USSR have yet to demonstrate that degree of stability.**
- **Cooperation experience – a year ago, the US and the USSR signed a space science agreement that established joint working groups in five areas. The efforts of these groups could lay the groundwork for a strong bridge of mutual cooperation and mutual trust".**
- **Technical readiness – both realise there are "many technical unknowns involved in a manned Mars mission," Fletcher said. Issues such as the effects of prolonged weightlessness on humans must be considered before Mars mission pacts can be made.**

In a more general vein, Fletcher labelled 1988 "perhaps the most critical year in the history of the US civil space programme" and he criticised those who say American leadership is a thing of the past.

"It's ironic that these doom-and-gloom sayers have emerged this year, just when the United States is poised to launch itself into a new era of development and exploration of space," he said.


SIMULATION
Antidote to Risk


SIMULATION
Antidote to Risk


SIMULATION
Antidote to Risk

Twenty-seven years have passed since Vostok 1 carried Yuri Gagarin on the world's first ever manned spaceflight and during those years space exploitation has come of age. Although public attention has focused on prestigious national space programmes with most people recalling only the major achievements and disasters of this pioneering period (spectacular spacewalks, the Moon landings and the Challenger disaster), man has witnessed an ever increasing use and reliance upon unmanned satellites for communications, Earth resources, meteorology, military intelligence and navigation.

To the layman the concept of space exploitation generally conjures up images of astronauts, rockets and vast budgets. The usual view is that space is a dangerous, remote and very expensive place, offering few obvious benefits, particularly in the short term.

There can be few of us, actively involved in the conquest of this high frontier, who do not despair at this short sighted view of space; a view which does nothing to encourage the large-scale funding necessary for space programmes in general, and fails to recognise the role of such programmes in motivating a nation and expanding its technology base.

by Lee Day and Graham Speed*

Reducing The Risk

Although the view of those outside the industry tends to provoke despair from those within, arguing a strong case for space is difficult because many of the benefits are as yet unknown or intangible.

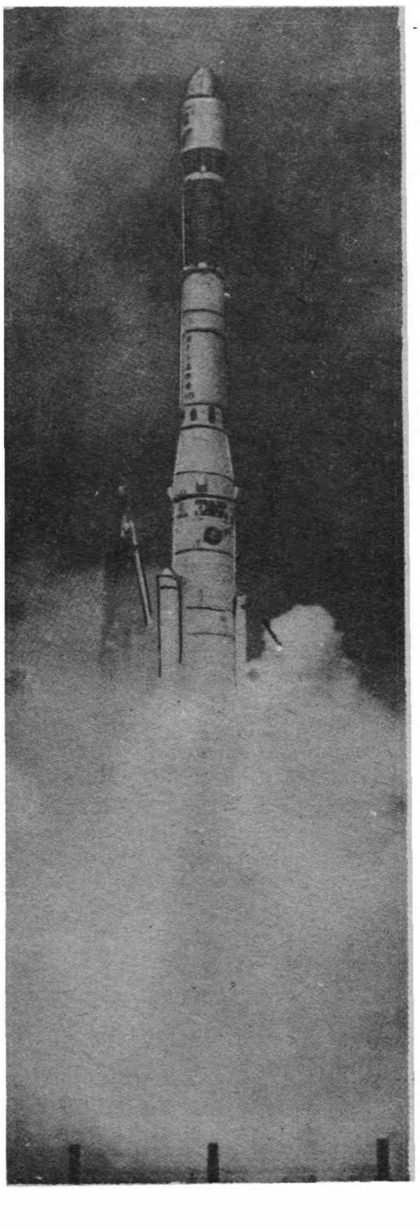
It remains a fact that gaining access to and exploiting space will continue to incur significant risk both in financial and human terms. The larger more ambitious space programmes with long schedules will by definition carry higher risks, especially as estimates have to be made to predict those technological developments most likely to succeed within the timeframe of a project. Success will then depend upon these developments being available for incorporation at the requisite time thus ensuring that cost, schedule, mass and power requirements are satisfied.

Many of the technical risks associated with the development phase of a space project can be evaluated and brought within acceptable limits through the use of a very powerful tool. The same tool dramatically reduces the human risk, and in particular the risk associated with human error. This tool is simulation.

It is not surprising that simulation has played a major role in training and mission support for manned missions since this has been its traditional role in the field of aviation ever since Ed Link built the world's first flight simulator (Blue Box) in 1929. What may be less appreciated is the invaluable role simulation continues to play in the development, verification and validation of both ground and space based elements of these high technology programmes.

Space programmes, because of their scale and complexity, depend upon the rigorous application of project management techniques. They involve maintaining a schedule in which multiple teams engaged in a range of activities, and situated in diverse locations, must co-operate. This enables the development of each of the subsystems, their components and interfaces to be coordinated so that the overall package will come together in a structured way. The system elements will thus become available when they are required and in a form which is totally compatible with other elements being developed in parallel.

Prepared? Not the time for doubts Launch is the culmination of methodical preparations in which simulation plays a key role *Arianespace*



The problem with a structured approach to space systems development is that verification of the complete system is not possible until the closing stages of the programme (a bad time to find that your calculations were wrong). Verification in isolation of system elements and their interfaces also presents difficulties as many systems are dependent for their operation on the outputs from other elements. In addition the very nature of these programmes precludes extensive test and verification in their operational environment (space); thus heavy reliance is placed on reproducing this aspect through various forms of simulation.

For verification during the early phase of a project, simulation is employed as a substitute for the missing system elements, thus enabling not only the testing of individual elements, but verification of the overall system design. This in turn permits modifications to the overall design prior to the manufacture of hardware, thus preventing the expensive and wasteful process of retrospective design changes.

Verification presents significant difficulties when considering a large geographically distributed system with a multitude of spaceborne platforms and Earth-based control centres. These difficulties are particularly acute in the case of a fully deployed Strategic Defence Initiative (SDI) system where, for reasons of national security, international politics, environmental protection, safety and cost, direct verification of the actual system is impossible. The ability to defend the West against a full scale nuclear offensive under a variety of possible attack scenarios can only be assessed through the use of high-fidelity simulation.

A Dual Role in Space

Space exploitation involves two principal types of risk – human and technical; these act independently and in combination, to create financial and schedule risks. The end result is a strong argument to discourage investors and restrict the scope of short to medium term objectives for space utilisation:

**Lee Day is Space Flight Manager in the "New Business" Department of Singer Link-Miles Limited and Graham Speed is Spacegroup Manager in the Engineering Department.*

Training Simulation

Human risk has been reduced through training simulation since the early days of manned speceflight when Link flight simulation provided the computer system and simulation software for the Gemini programme. Rigorous training in routine procedures and contingency measures is the key to astronaut safety upon which mission success depends, and since access to space for training purposes is neither practical or desirable, simulation offers the only alternative.

Furthermore, in the event of an unexpected failure during a mission, simulators are invaluable and even life-saving, as in the case of Apollo 13, where Link's Command and Lunar module simulators were used to test and validate hitherto untried emergency procedures (using the Lunar module as a lifeboat to tow the command module back to Earth orbit). In this case simulations were performed to establish how long fuel, water, oxygen and other consumables would last, how much time and power would be needed to separate from the service and lunar modules prior to re-entry, as well as how to navigate and make course corrections with the inertial platform powered down and the Lunar modules engine being used to drive the combined Lunar, Command and Service module.

Training Analysis

Training simulation for ground control personnel and flight crews plays a central role in mission success whether the mission is the day to day monitoring and control of a satellite, or the in-orbit assembly of a space station. To meet this challenge major simulation companies such as UK-based Singer Link-Miles are focusing more and more on 'training analysis' as a means of providing an overall training system tailored to the desired proficiency levels of individual personnel who together are responsible for operation and control. Such a training system would utilise facilities ranging from the classroom through to full mission and networked systems simulations. Training analysis ensures that all aspects of the training requirement are fully understood prior to formulating the most cost-effective training package.

This approach includes not only analysis of the task for which the training is required but also the characteristics of the trainees likely to be selected. The final training package, when operational, forms a structured progression incorporating only those stages shown by analysis to be necessary, for example, academic lessons, Interactive Computer Based Training [CBT], Part Task Trainers (such as maintenance trainers or cockpit procedures trainers), Simulators (such as Full Flight Simulators or Full Mission Simulators) and integrated networks of a number of simulators.

This latter stage would be the culmination of training for the crew of a space vehicle or station, the ground controllers and the mission-related payload user and control personnel.

Simulation For Verification

As stated earlier, simulation enables the verification of complex systems and individual system elements during the development phase of a project, when the system hardware and software is largely incomplete. For systems of a manageable size which can, after integration, be verified in their own right, simulation is implemented in stages. This enables valuable performance data to be generated, providing feedback to the design team throughout the development of the system.

For example, space station elements such as the Columbus Attached Pressurised Module (APM) or the Japanese Experimental Module (JEM) can be regarded as large complex systems of manageable proportions. As these space station elements are to be 'man-rated', system verification is a critical element, mainly due to the interdependence between reliability and safety.

For a JEM/APM type development programme, simulation begins early in the overall development schedule to enable astronaut feedback to influence the 'man-machine interface' (MMI) aspects of the design. This is known as man-in-the-loop simulation. During this early phase hardware mock-ups and simple software models play a predominant role and it is these software models which form the preliminary building blocks for the total verification simulator (usually known as an integration laboratory).

The next phase involves linking together these software models and certain hardware mock-ups so that progressively larger simulations of the system can be performed. By this time some prototype system elements will be available and can therefore be integrated with the overall simulation. This enables their operation and interfaces to be tested and verified as well as the impact of these items upon the functioning of the overall system. From this point onwards the evolution of the integration laboratory, and therefore the system under development, is set.

As the project proceeds, more prototype equipment becomes available and is substituted for the software models in the simulator, until a point is reached where the total system is in place and the only simulations present are the environmental simulations and data links used to 'stimulate the system'.

The facility also becomes increasingly useful during this evolution for mission planning and preparation, by allowing operational procedures to be developed and evaluated in a realistic manner. Furthermore, communication with external elements, such as ground control centres, provides a means of developing and qualifying the overall infrastructure in addition to the subject vehicle or platform.

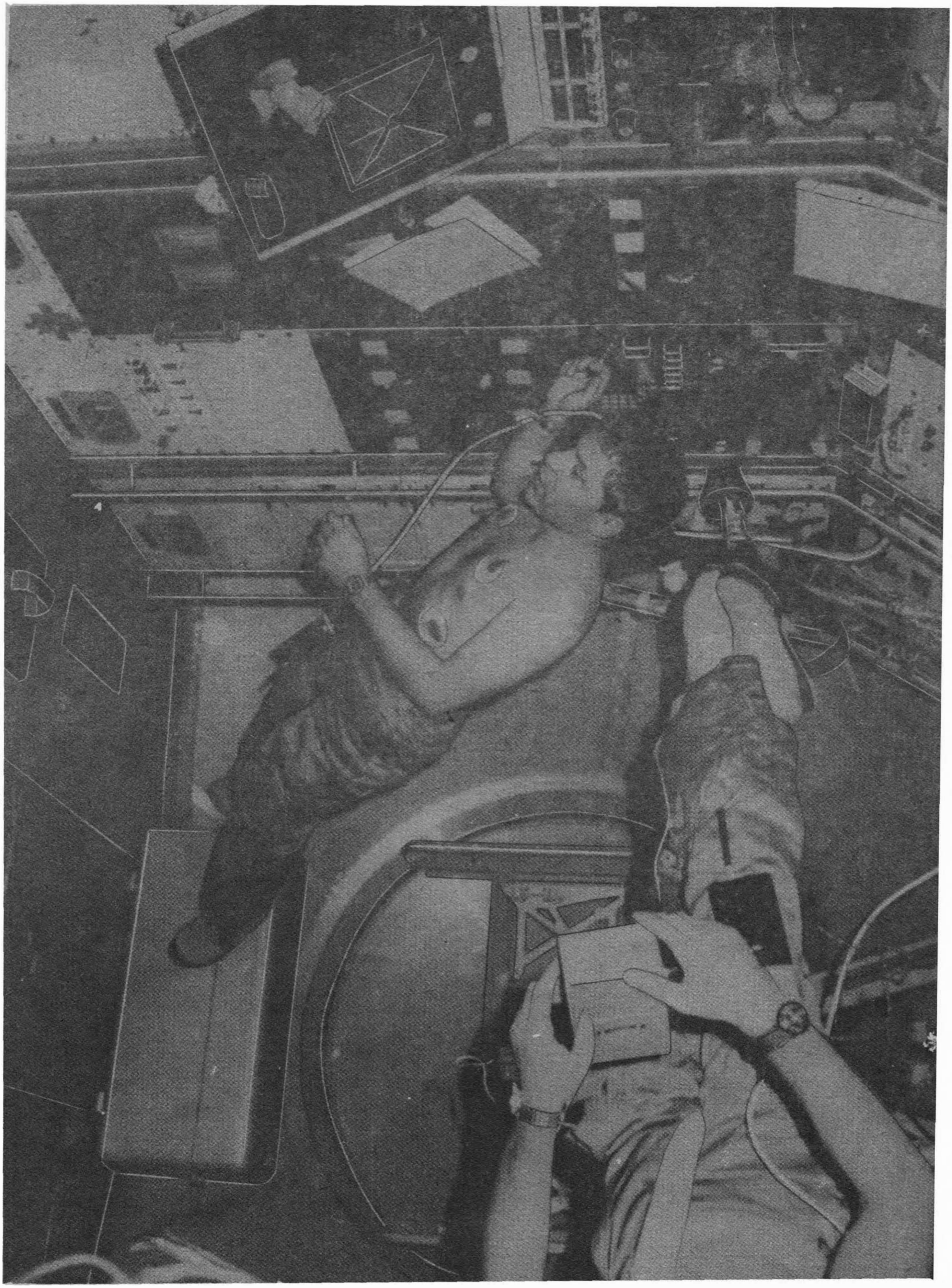
This approach ensures that most of the technical problems and MMI aspects of the design are solved prior to final integration of the complete system thereby dramatically reducing the requirement for 'last minute' modifications and ensuring that the system specification is met, on schedule and within budget.

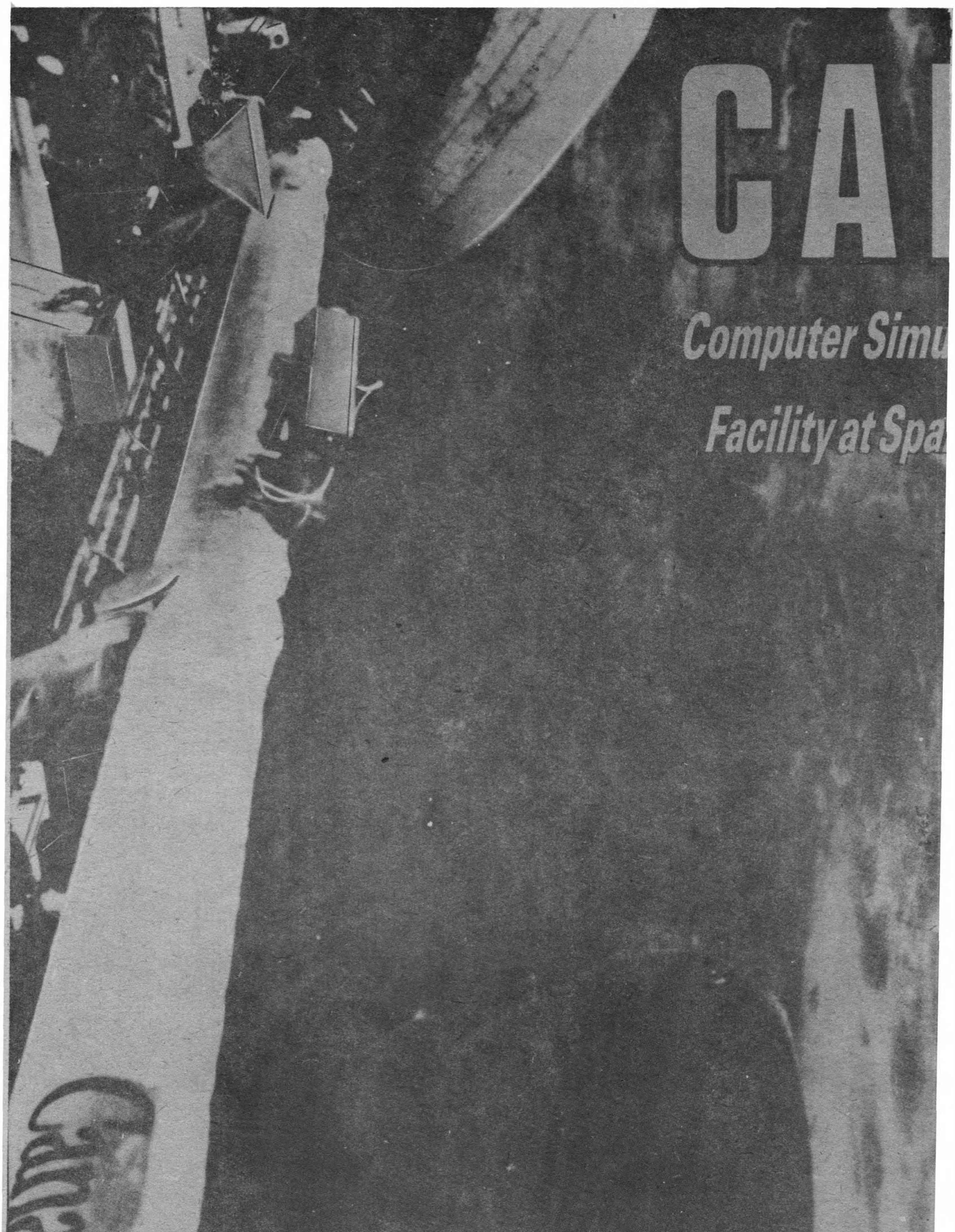
Although the largest contribution of simulation occurs well before launch, once a system is in space its role is nonetheless vital. Truly autonomous missions remain concepts for the future, and in the meantime heavy reliance will continue to be placed upon support from the home base, be it on Earth or some orbiting platform. Such support will be necessary both for routine planned operations as well as countering the malfunctioning or unforeseen, to help ensure a safe and successful mission. By definition the remoteness of this support activity will necessitate simulation.

The future promises an ever increasing utilisation of space not only for communications and Earth resources purposes but for the in orbit manufacture of medicines and materials which require for their purity and structure a microgravity environment; looking even further forward, the establishment, in space, of solar power stations may provide humanity with a viable alternative to the otherwise inevitable energy crisis which will result from the exhaustion of the planet's non-renewable resources. Risk will, however, continue to be a fact of life for investors and astronauts alike.

A direct consequence of this omnipresent risk will be an ever increasing reliance on simulation in its various roles. Although simulation alone will never make space exploitation 'cheap' or safe, it will add a vital dimension (confidence) to the endeavour, thus reducing the need for bravery when making decisions for investment in or design and operation of space systems.

Simulation or reality? The presence of gravity should be the only discernable difference. This picture was actually taken during the Spacelab 1 mission in 1983 and clearly demonstrates the microgravity conditions of the European-built laboratory. *NASA*





Canadarm over the Holy Land.

NADARM

ation

Aerospace

by Peter Jedicke and Clifford Cunningham

A tense moment in Earth orbit: a malfunctioning satellite is drifting away from the space shuttle and a rookie mission specialist stands in the aft portion of the Orbiter flight deck. A difficult mission is planned and the commander hopes he will not need valuable fuel to catch the errant satellite. The mission specialist reaches for the shuttle Remote Manipulator System's controls – the famed Canadarn. Swiftly she jockeys the 15 metre appendage around, switching with confidence among the various automatic and manual modes of operation. The grapple light comes on. It is a perfect catch. She has been in space less than a day, but she has done this a hundred times.

A communications satellite is delicately manoeuvred into the space shuttle's' cargo bay by the Canadarm. An astronaut operating the arm in such a manner will have spent many hours practising on the simulator at Spar Aerospace.

Learning how to use the Canadarm before there was a Canadarm at all was the challenge faced by engineers at Spar Aerospace Limited in Toronto, where the shuttle Remote Manipulator System (RMS) was invented.

The result was a facility that might be thought of as Canada's most sophosticated video game – perhaps even a "video reality". It is a computerised simulator that has allowed astronauts to develop expert skills in remote manipulator systems, and given the engineers a valuable tool to aid them in their design innovations. The astronauts themselves have crowned Spar's success with compliments about how precisely the simulator mimics the behaviour of the Canadarm in space.

Peter Jedicke and Clifford Cunningham*

An adequate understanding of how Canadarm would not only swing, rotate, extend and pitch but also shake and bounce could only be based on complicated dynamical equations. These equations arose largely out of studies done by Peter Hughes of the University of Toronto's Institute of Aerospace Studies on the flexibility and control of spacecraft. In particular, Hughes had studied the apparently anomalous behaviour of Canada's Alouette satellite, sent into Earth orbit in 1962 [1].

To stabilise Alouette it was set spinning, but it gradually slowed, began to tumble and control was lost. Hughes and his colleagues realised that Alouette's long, spidery antenna were to blame. Contemporary models had considered Alouette – and all satellites – as rigid bodies. A rigid body has six degrees of freedom; three of translational motion as well as pitch, yaw and roll. But Alouette's antennae were not rigid; they oscillated as it spun. The oscillation set up a cyclical heat conduction and rotational energy was ultimately dissipated.

To model such a "non-rigid body", an abitrary number of points in the body must be selected. The more points that are selected, the more accurately the model will represent the actual body. But the price of selecting more individual points is that there are six degrees of freedom for each free POINT within the model. If an object is modelled by 1000 free points, then it has 6000 degrees of freedom! Each degree of freedom involves an additional equation which must be solved by the model.

Even in the early stages, NASA and Canada's National Research Council (NRC) were co-operating on these studies and when the need for a remote manipulator system for the space shuttle was identified, Canada expressed interest.

Spar Aerospace was brought in to tackle the project. While the development of the actual hardware for what eventually became the Canadarm went on in parallel, engineers at Spar used FORTRAN computer software to model the behaviour of the arm, as predicted by the equations of Hughes and the development engineers. The simulations began in the mid-seventies with the development of a program called ONEJNT, the goal of which was simply to model the motions of a single joint.

The first attempt to mimic the entire arm, with its six active and two passive joints, was called SPARMS. Each section of the arm was considered as a rigid body. SPARMS not only investigated the behaviour of such a simplified arm, but also tested the algorithms being implemented to control the arm's mechanisms. Engineers working on hardware and software worked closely together.

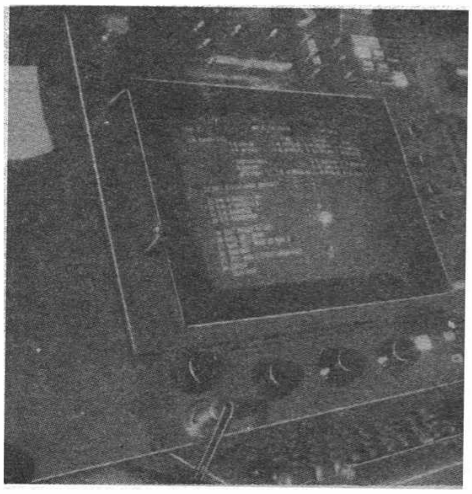
Next came work on a full-scale computer simulation of the complete arm system, with the goal of making a model whose behaviour in the computer would be indistinguishable from the actual behaviour of the Canadarm in space. The arm needed to be lightweight and would bend and flex: the model had to include this. In fact, the arm's oscillation varies in frequency from about 0.3 Hz with no payload to about 0.03 Hz with a heavy payload. Payloads in the space shuttle orbiter's cargo bay which can be handled by the Canadarm can be up to 30,000 kg and measure 4.5 metres in diameter and 18 metres in length [2]. The approximations used to make the simulation's mathematics tractable had to introduce less error than the sensors testing the arm's hardware could detect. The program and the prototype had to verify each other in quantitative terms.

To tackle this assignment, Spar engineers settled on an Euler formulation with up to 72 degrees of freedom. The complete software package now incorporates up to 30 selectable flexible modes and includes the capability to vary virtually every parameter of Canadarm's engineering design, manual and automatic control and actual performance, such as positioning, deployment and retrieval of payloads. The program also calculates critical limits on the various loads induced by sudden movements and other situations that would be encountered. Five basic modules were developed: arm dynamics; joint servo and gearbox; arm control algorithm; orbiter attitude control system; and display. The display module can follow the variables listed below:

- Orbiter attitude angles and their rates of change.
- Angles at the arm joints and their rates of change.
- Angles of freeplay and their rates of change.

Exterior of the Spar simulation facility.

Canadarm simulator work station.



- Torsional deformations and rates of different links.
- Generalised co-ordinates and rates of change for lateral bending of links.
- Position an orientation of the end of the arm.
- Position and orientation of the payload.

This ambitious project, as was realised at the outset, is not capable of performing all of these "hi-fidelity" functions in real time. It simulates everything about Canadarm except the speed. The output, appearing on a terminal or a hardcopy, gives the engineers a complete picture of the behaviour of the arm. In the best spirit of computer jargon, the program was named ASAD, an acronym for "All Singing, All Dancing" – it could do everything!

But everyone at Spar knew that a

** The authors visited Spar's RMS Division in April 1987 and wish to thank Jim Middleton, Vice-President of Spar Aerospace RMS Division, and Phung K. Nguyen, Staff Engineer.*

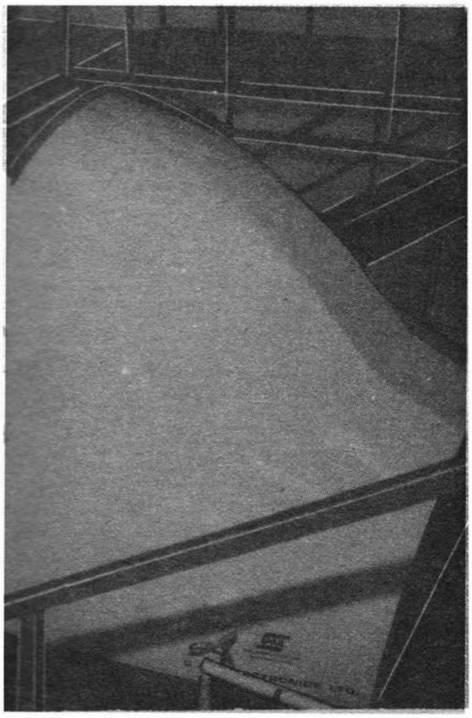
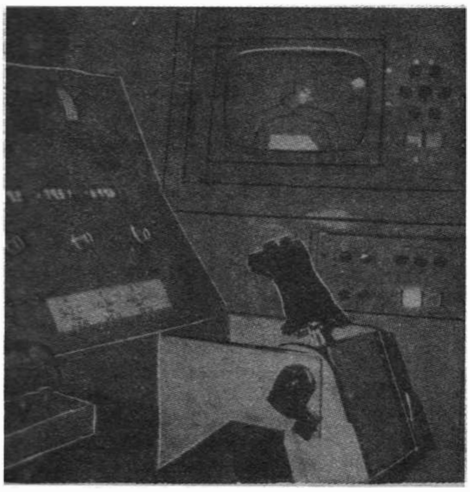


Photo: C. Cunningham

Spar



real-time simulator would also be necessary for training purposes. The result was SIMFAC, (the SIMulation FACility) in which the speed necessary for real-time operation is achieved by sacrificing some finer engineering details, such as all harmonic frequencies higher than 10 Hz, and restricting the number of degrees of freedom to 23.

There are four major parts to SIMFAC: master control, the operator complex, simulation system and the scene generation system. All are installed at Spar's RMS Division in Toronto, in a room about the size of a small house, with a tall glass wall looking into the cavernous engineering "clean room" where the Canadarms themselves were assembled and tested.

Master control looks like any large computer room, with stations for a test conductor and a systems engineer. Scene monitors, hardcopy printers and a bank of 18 analog meters which monitor various critical parameters are included. All of SIMFAC can be controlled from master control, even the functions of the operator complex. Next to master control are the banks of computer cabinets and tape drives that house the simulation system.

Like a mezzanine, all of this is on the second floor and overlooks the operator complex next to the glass wall. The operator complex is actually adapted from the cockpit unit of a DC9 simulator, which is similar in size to the space shuttle orbiter's flight deck. Two large, rectangular boxes attached like parasites to the simulator house the video generators of the scene generation system.

The inside of the simulator is not nearly so impressive as that of a full-scale orbiter mock-up. There is nothing but a blank gray wall facing "forward". But the operator station presents bank after bank of switches and rows of digital readouts. One "window" faces "backwards" and another up, where the scene generators show line drawings in white on black of what would be visible from the Canadarm's operator station on the orbiter itself. An infinity lens system enhances the depth perception when looking into these screens, so that the effect is amazingly realistic. The key to the whole affair is the two hand controllers: for the left hand, a large knob at shoulder height located to the left of the rearview screen, and for the right hand, a pistol-grip controller at waist level beneath the control panel. Finally, two additional CRTs on the operator's right normally show the scenes as viewed by the cameras on the arm itself and there is a computer screen and keyboard at the left.

The simulator was built by CAE (Canadian Aviation Electronics) of Montreal, which manufactures a variety of simulators for the aviation industry. The scene generation system was constructed by the Canadian subsidiary of RCA, which has since become a part of Spar Aerospace. Because NRC paid for its development, the simulator is still owned by the Government of Canada. There are over a dozen similar simulators accessible to NASA, each focusing on a different aspect of the mission profile. For instance, the simulator at Johnson Space Centre is used primarily for integration of all mission operations. In order to train specifically for the use of the Canadarm, astronauts often spend time at SIMFAC.

Using the Canadarm simulator is very much like playing an intricate video game. A dizzying variety of settings must be selected on the control panels; for instance, all six operational modes, from fully automated through a variety of manual controls, can be simulated. Or the profile can be called from pre-set situations stored in the computer. The payload is also included in the scene generation.

Once the simulation begins, the operator uses both hand controllers to move the arm's end effector toward the target, while watching the unfolding operation on all the screens. The computer software can generate the images so that they block each other as they pass in front of one another, or they can be see-through, so that all details are visible, even on the opposite side.

After crashing the end effector into the payload or the cargo bay walls a few times, a neophyte operator can learn to think through the motions. The operator learns very quickly not to use a rapid tapping on the controller, which works so well in a video game, because the repeated starts and stops soon make Canadarm oscillate dramatically, and it takes more than a minute for the arm to settle down.

Imagination quickly blots out the rest of the mundane simulator and the operator is transported to a heroic scene in Earth orbit: the grapple fixture on the LDEF is a metre from the end effector, but the angle is all wrong. Luckily LDEF is not spinning! With a few deft manoeuvres and 90 seconds of pounding heartbeats, the capture is complete. After just a few hours of practice, astronauts in training usually do not make any more embarassing mistakes. It takes a few days to develop enough skill to really use the system and many weeks to become expert.

Development of Spar's simulator capability will continue with what has tentatively been called MDSF, the Manipulator Dynamics Simulator Facility. Engineers are still working on the best compromise between which mathematical model to use and the economics of computer capabilities and simulation needs. It is hoped that MDSF will combine the abilities of ASAD and SIMFAC – and be at least ten times as fast as ASAD. Also, MDSF will have the ability to interface with real hardware. Spar is hoping to simulate contact and deformation of assemblies and the constraints included in a "closed chain" when payloads in space are hooked together. Scene generation will be in colour and will be more sophisticated when a real-time simulator eventually grows out of MDSF to replace SIMFAC.

The Canadarm itself will soon be grandparent to a new generation of remote manipulator arms which will carry a significant burden during the assembly of the international space station. Such manipulators will be part of the Mobile Service Structure, which will be Canada's contribution to the international project. When astronauts take to the high rigging, their experience will be based on many hours battling the great video game of SIMFAC and its grandchildren.

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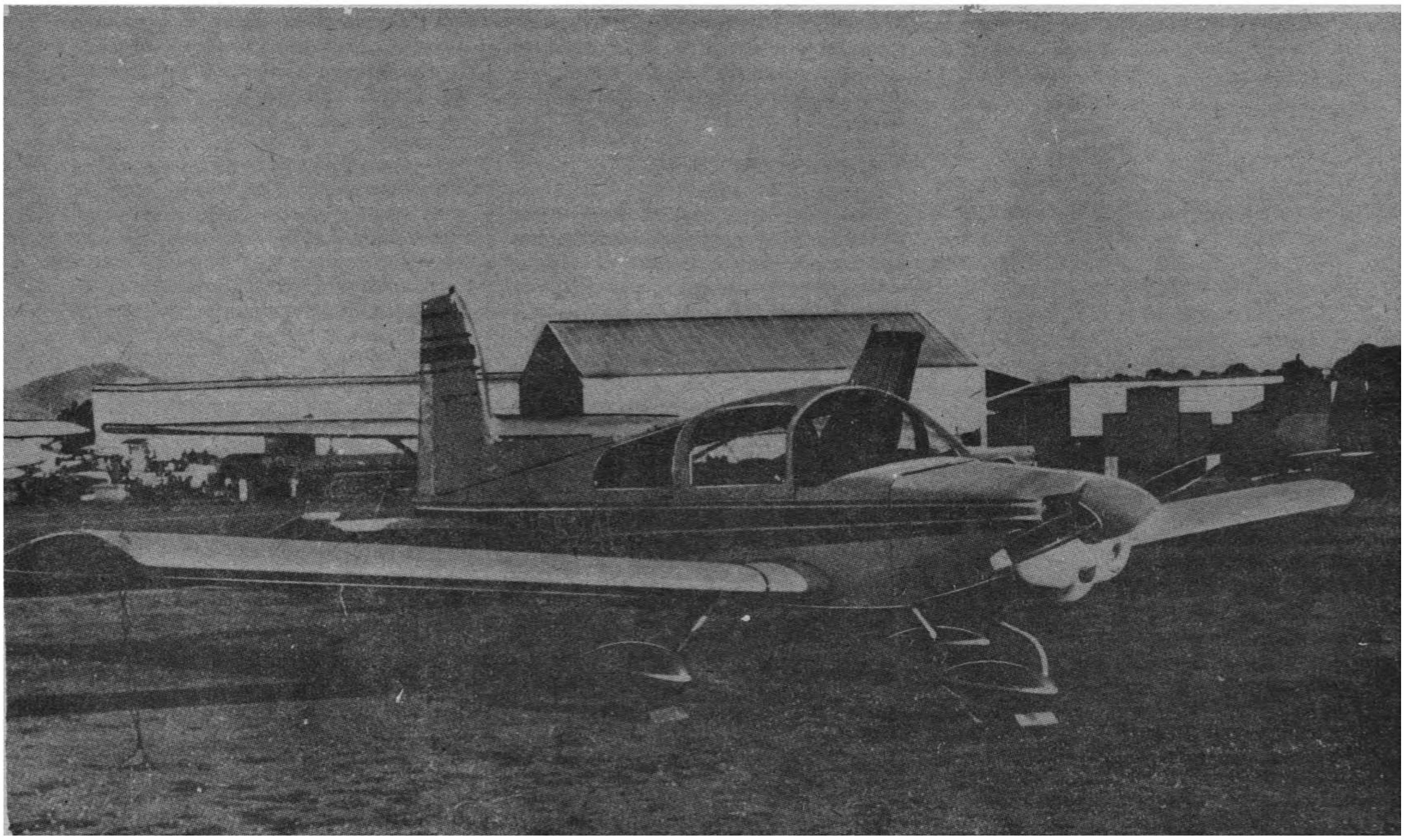


The Grummann Traveller light aircraft used for the majority of the author's weightless flights The entry speed into the parabolic arc is about 210 km/hr The aircraft climbs about 150 metres to the peak of the arc and aircraft speed at the peak is about 110 km/hr (just above stall speed) Weightlessness lasts between three and five seconds. *Peter Campbell*

Flying the Weightless Profile

by Curtis Peebles

There are few people who, seeing an astronaut floating weightless, have not wondered what it is like. It is a wish that would seem impossible to fulfil short of going into space. Weightlessness can, however, be reproduced by flying a parabolic arc. Jet fighters and NASA's KC-135 have long been used for weightlessness training. However, what is not generally realised is that a light aircraft is also perfectly capable of flying the weightless profile. Chris Peebles, who is a Fellow of the Society, had the opportunity to make a number of such flights and here reports on this area of work and his own experiences for readers of *Spaceflight*.

Ways and Means

A crewman of an orbiting spacecraft is weightless due to a balancing act between the centrifugal force due to the orbital velocity and the gravitational pull of the Earth. As there is no relative motion between the interior of the spacecraft and the crewman, the crewman seems to float in mid-air.

An aircraft in normal flight experiences weightlessness for very brief intervals under certain conditions – when caught in a downdraft, during spin recovery and in a dive. A French text in 1918 noted the phenomenon and reported that it produced insecure control movements by the pilot. Research in the area at that time, however, was extremely limited [1].

Prolonged weightlessness was first experienced by Luftwaffe pilots during attacks on US bomber formations. The pilots would make a dive from high altitude to gain speed, then a sharp pull up into the firing pass, followed by a push over into a dive to escape. During the push over, the aircraft becomes weightless. Initially the pilots reported disturbed vision and weakness in the legs along with insecure control movements but with experience some pilots said they found weightlessness an enjoyable experience [2].

The explanation and the possibility it opened up were outlined in a May 1950 paper entitled "Possible Means of Producing the Gravity-Free State for Medical Research". Written by Fritz and Heinz Haber, two German scientists working at the Air Force School of Aviation Medicine, it noted the manoeuvre was actually a parabolic arc. When the push over is made the aircraft is following the type of trajectory a satellite would have in a very elon-

gated orbit around the Earth's centre of mass. As the engine's thrust is cancelling out air resistance, the airplane's path mimics a true orbit (from the point of view of basic physics) and the airplane is weightless. The duration of the period of weightlessness is dependent on the speed of the aircraft. A light plane can maintain it for three to five seconds, a subsonic jet for 15 to 45 seconds. In a supersonic jet, it can last up to a minute and in a rocket plane, like the X-15, for several minutes [3]. Ultimately as the speed increases, it is no longer a simple curve but rather a true sub-orbital trajectory.

The Habers' paper set in motion several weightless research projects. During the summer of 1951, test pilots Scott Crossfield and Major Charles E. Yeager, made a number of parabolic trajectories at Edwards AFB. In Argentina, Dr. Harold J. Von Beckh, an Austrian scientist, also made tests using a Fiat fighter. Both humans and animals, specifically South American water turtles, were tested. The water turtles were used because of their long S-shaped neck which they use to strike at their food. Any changes in muscular coordination were, therefore, easily recognisable. On some flights, the water turtles, and the water itself, rose out of the tank and Van Beckhn then had to fit the tank back around the floating blob of water and turtle!

In 1953, the US Air Force resumed weightlessness studies at Holloman AFB. The aircraft used were T-33 and F-89 jets and the programme was under the direction of Major David G. Simons. In the autumn of 1955, Captain Grover J.D. Schock, the holder of the first PhD in space medicine, joined the

Payload Systems president and shuttle astronaut Byron Lichtenberg with Gay King during operation of a fluid physics experiment aboard the KC-135.

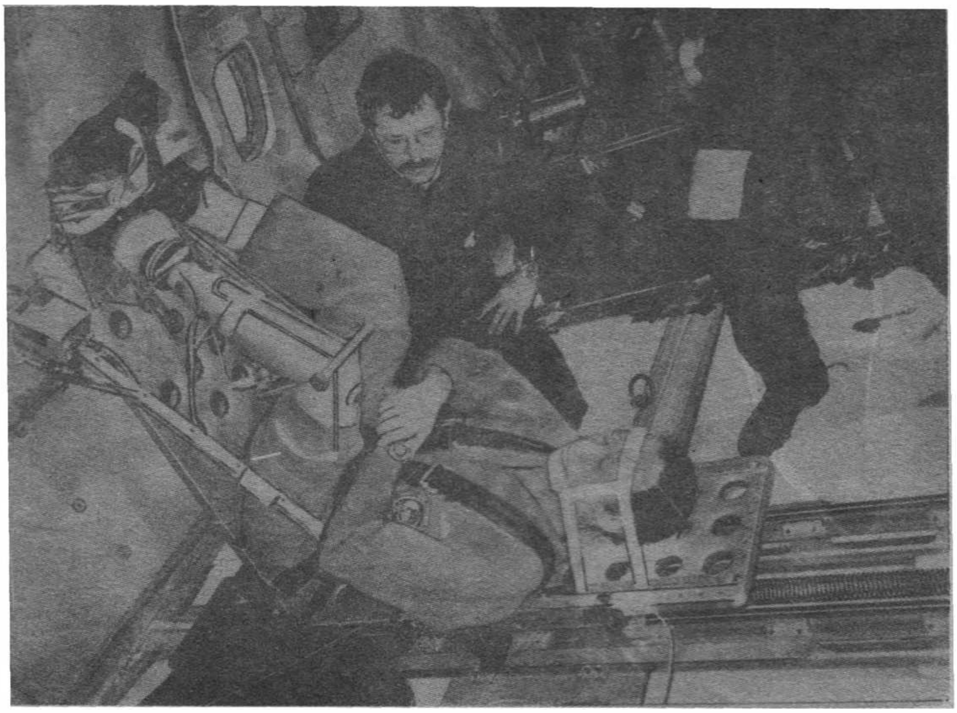
Microgravity Research

Missions under NASA Johnson Space Center's 'Reduced Gravity Program' are being organised on a quarterly basis by Payload Systems Inc.

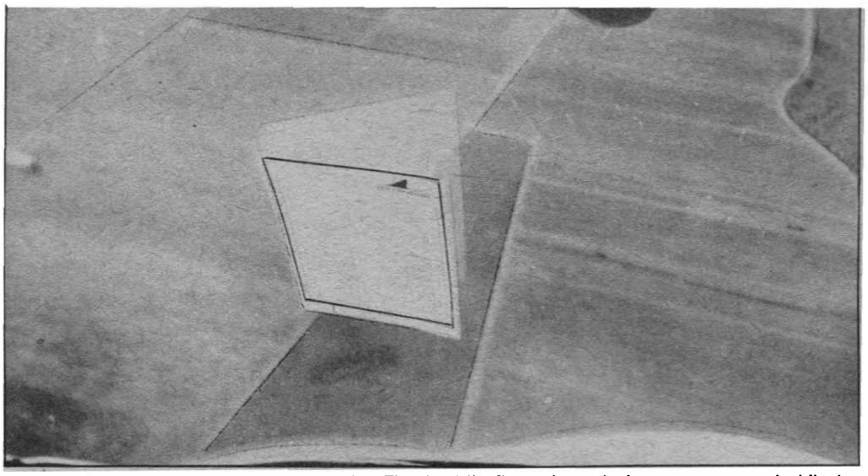
The latest in the series of missions, which allow scientists to further develop their microgravity experiments, took place at the end of March and attracted over 30 researchers from the US, Canada, Japan and Germany.

With the US Shuttle grounded, the KC-135 provides microgravity investigators with the only meaningful opportunity to assess the effects of weightless conditions on their tests and equipment. The results will enable them to better define the optimal equipment, training, and operation requirements for shuttle-bound experiments.

The KC-135 (a modified version of the Boeing 707) is flown in a parabolic trajectory manoeuvre which provides zero gravity for approximately 25 seconds per manoeuvre. A typical flight consists of 40 parabolas and lasts two to three hours.



Biomedical researcher from McGill University in Montreal operates an experiment designed to explain the effect of reduced gravity on the human inner ear and balance functions.



A photo taken during a weightlessness profile. The check list floats above the instrument panel while the green fields of Earth await below. It is floating that creates the strongest inpression of weightlessness. Both the sight of objects suspended in mid-air-defying a lifetime of experience and the physical sensation of floating without falling. *Photo: C. Peebles*

programme. The aircraft was also changed to a higher performance F-94C.

At the same time, a research programme was started at Randolph AFB. The initial aircraft used was a T-33. However, stability problems made research difficult. It was hard to fly an accurate parabolic arc with a gravity fuel flow that posed the risk of a flame-out during weightlessness. The T-33 was replaced by the F-94C already in use at Holloman. With a pressure fuel flow and an afterburner, the F-94C could provide smoother and longer (over 40 second) profiles [4].

As with all pioneering efforts, there were problems – loss of oil pressure, hydraulic fluid and "sticking" of the trim tab motor, which made flights "interesting". A smaller problem was that standard microphones did not work in weightlessness and a substitute had to be developed [5].

Test instrumentation also had to be developed. At first the test for weightlessness was to toss a pencil into the air or watch a golf ball on a string, which was taped to the canopy. If they floated, the plane was weightless (the standard G-meter was not sufficiently accurate).

Needless to say, these crude methods could not measure, much less record, the flight variation in weightlessness. In time, Schock developed a system of several accelerometers which indicated the precise G-forces to the pilot. This data was synchronised with a film of the test subject's reactions. Unfortunately, this equipment also cluttered the already cramped cockpit and complicated flight safety.

Budget factors also entered the picture. In the summer of 1957, an austerity drive closed down the F-94C research programme (the plane cost $63 per hour plus maintenance and overheads to operate) but funding was re-instated that autumn. Despite such interruptions, an impressive number of profiles were flown and by April 1958, Major Herbert Stallings, the test pilot for the Randolph AFB flights, had logged 37 hours of weightlessness in more than 4,000 profiles.

The same year, researchers at Wright Patterson AFB began using a C-131 aircraft for weightlessness tests. Although capable of only 10 to 15 seconds of weightlessness, its large volume allowed tests of several individuals at one time. The experiments included the ability to manipulate switches and tests of magnetic and suction cup shoes. The C-131 also saw the first flights for women in weightlessness [6]. During the 1960s, NASA and the Air Force began using KC-135s, giving longer duration flights of up to 3C seconds.

The Experience of Weightlessness

So much for the pioneering efforts – what is weightlessness *like*? The profile begins with a sharp pull up into a 30 degree climb. This subjects one to increased G-forces. As the plane climbs, the seat and floor press against the passenger's body. This, along with the downward pull of gravity, causes the sensation of increased weight. It is not a pleasant feeling. Your arms are heavy as if the bones have turned to iron. It requires more effort to move than normal. Moreover, if the shoulder strap is loose, the increased weight of the head and upper body causes you to lean forward towards the control panel. This creates the illusion that the plane is climbing almost straight up. This is definitely not the fun part!

As the plane nears the peak of parabolic arc, the oppressive G-forces ease, dropping from two Gs to one and lower. Then the magic starts. With no fuss or bother and in defiance of a lifetime of experience, a pen sitting on the instrument panel, begins floating in mid-air. Then you realise you are too. There is a gap between your body and the seat cushion. Your arms are floating at shoulder level and your feet have risen off the floor. But you are not falling; it is as if the thin air is providing perfect support. The pressure, on the soles of your feet, back and legs from gravity, is gone. You have broken the chain of gravity. For me the strongest impression is visual. Pens and books are floating in mid-air. Their movements are smooth and seemingly in slow motion with none of the jerkiness of a thrown object. A pen caught by a stream of air from a vent is carried to the rear of the cockpit with a frictionless smoothness. This is the fun part.

The contrast is striking. Visible through the windows are hills, fields and farm houses. Down there for the earthbound, when objects are dropped, they fall. But not here – the normal rules do not seem to apply. For a few moments, it seems you really have cut all the ties with Earth.

During the mid-1950s, the reaction of 47 people to weightlessness was studied at Randolph AFB. A common reaction was a feeling of floating. A few reported a sensation of falling. This was despite a common belief, at the time, that a feeling of continually falling would occur. A small number suffered from disorientation, nausea or motion sickness. It appears this was mainly due to apprehension and fear [7]. For me, the only way to describe this strange, other worldly sensation, is fun!

But all fun things must end. The plane reaches the "apogee" of its "orbit" and begins the long fall toward the Earth's centre of mass. The Earth, of course, is not a point scurce but very wide and quite hard. The green fields of Earth start to grow larger. It is time to pull up. At this point, the plane and passengers are heading towards the "perigee". As the plane pulls up, the passengers' bodies tend to continue downward (as during the climb). Again, one is subjected to the uncomfortable feeling of multiple Gs. When pull-up begins, I frequently have the feeling I am sliding forward. The eyes grow wide and there is a fast grab for the instrument panel. The reason for this is that the airplane's engine will frequently start to lose thrust as the period of weightlessness continues. It is, therefore, unable to compensate for air drag. Free floating objects in the cabin remain in their previous position. It is the surrounding airplane which is actually pushed back. There follows a feeling of heaviness until the plane is in level flight and the profile is completed.

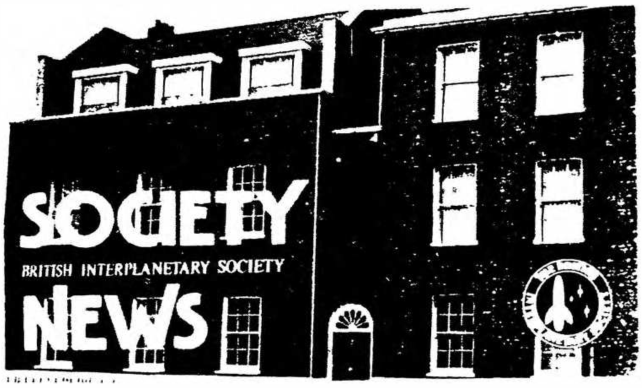
References

1 James Stephen Hanrahan and David Bushnell *Space Biology* (New York Basic Books 1960), 111, 113, 120
2 Eloise Engle and Arnold Lott, *Man in Flight* (Annpolos Leeward Publishing 1979), 270
3 *Man in Space* Lt Col Kenneth Gants, Editor (New York· Duell, Sloan and Pearce 1959), 112-115
4 Hanrahan and Bushnell, *Space Biology*, 135-138
5 Engle and Lott, *Man in Flight*, 273, 274
6 Hanrahan and Bushnell, *Space Biology*, 139-141
7 *Man in Space*, 124, 125

The author has made weightlessness flights on the following occasions November 3, 1979 (3 profiles), May 11, 1980 (4 profiles), February 9, 1985 (5 profiles), November 15, 1986 (3 profiles), and December 7, 1987 (5 profiles)

Special thanks are due to Peter Campbell and Phil Henderson

Note Because the climb angle may exceed 30 degrees, it is necessary for the aircraft to be stressed for aerobatic flight Also, prolonged weightlessness may cause the engine to cut out or temporarily lose oil pressure, caution is necessary at all times



Top Speakers at Space '88

The Society has now announced a preliminary programme of speakers for its SPACE '88 **weekend to be held in Hastings at the end of September.**

Among well-known names are Dr. Bill McLaughlin, from the Jet Propulsion Laboratory in California; Roy Gibson, special adviser to Inmarsat and former head of BNSC; Dr. Bob Parkinson, a key member of the UK's Hotol team; and Dr. Garry Hunt, planetary scientist and a regular guest on Patrick Moore's 'Sky at Night' programme.

Speakers and topics for **SPACE '88** now include: Dr. W.I. McLaughlin (A Philosophy of Space Exploration); Dr. L. Suid (Space & Mankind: The Writer's View); H.J.P. Arnold (The Image of Space); R. Gibson (Britain in Space: A Philosophical Approach); A.T. Lawton (The Future Role of Trans-Atmospheric Vehicles); P.J. Conchie (Aerospace Vehicle Operations in the 21st Century); A.T. Lawton (Making Semi-Conductors in Space); Dr. N. Loukes (Spin-off: Present Indicatives); D. Webber (The Future of Satellite Mobile Communications); Dr. R.C. Parkinson (Citizens of the Moon); Dr. G.E. Hunt (Some Aspects of a Mars Base); M. Pollizer (Space Interests of the United Nations University) and Dr. D.W. Hughes (Exploring Comets and Asteroids).

Other papers are in the course of arrangement and there will also be live demonstrations of space activities by students of Acton High School and exhibitions by Marconi and British Aerospace.

A free information pack on the **SPACE '88** weekend can be obtained by writing to the Society enclosing an sae.

New Range of BIS Wear

The new BIS range of clothing is already proving highly popular with members both at home and overseas.

A special leaflet was inserted with members' copies of the May edition of ***Spaceflight*** advertising the brand new items.

This, together with an order form, has been reproduced again overleaf – just in case you've mis-laid the original, or for interested non-members who have not seen the clothing before.

In addition to the summer sports and T-shirts, sweatshirts and ties, the Society's logo is also available as an embroidered sew-on patch (for jackets, bags, blazers etc.) at £2.50 (US$5), a pin-on badge at £2.50 (US$5) and a car badge at £7.00 (US$13). These can also be ordered on the form overleaf.

Any of the items would make an attractive gift for a space enthusiast friend or relative. And remember – all profits go to the BIS Development Appeal.

Membership Boost

Welcome news to come from the Society's Subscription Department is that the end-of-year membership figures for 1987 show a significant year-on increase. The total for Member and Fellow grades now stands at 3604 compared with the 1986 figure of 3381.

For many years previously the Society's membership has remained nearly constant with a fine balance maintained between new admissions and non-renewals. It is interesting to note that at the end of the 1950's the total was at a similar level, being 3303 in 1959.

The 1987 increase is closely related to an upswing in new admissions – a trend that appears set to continue in 1988, with many now opting for BIS membership after buying ***Spaceflight*** magazine for the first time from their local newsagent.

Commenting on the figures, Mr. Len Carter, BIS Executive Secretary, said they contained no grounds for complacency. "This upward trend must be maintained to give the Society the strength and resources to enable it to extend its role in promoting space and astronautics," he said.

Regarding reasons behind the increase, Mr. Carter added: "The Society's work becomes ever more important in the light of events both in this country and internationally so that more people seek membership to align themselves more fully with the Society's activities."

Maria Schuminszky (above), wife of BIS member Nándor Schuminszky, at a Space Research exhibition in Gyomaendrod, Hungary.

The exhibition, which included a small display on the 38th IAF Congress (right) hosted last year by the Society, was organised by Mr. Schuminszky with the help of Hungarian back-up cosmonaut Béla Magyari.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

1 June 1988, 7-9 pm **Lecture**

HOTOL – A SPACEPLANE FOR EUROPE

Dr. R. C. Parkinson

Due to a popular demand this will be a repeat of the lecture given by Dr. Parkinson on March 9.

Members only. Please apply for ticket as soon as possible.

4 June 1988, 10-4.30 **Symposium**

SOVIET ASTRONAUTICS

Venue: Conference Room, British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ.

Offers of Papers
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Executive Secretary, The British Interplanetary Society, 27/29 South Lambeth Road, London SW8 1SZ. Tel: 01-735 3160.

25 June 1988, 2 pm **Visit**

RAF Cosford Museum

Cosford contains a major collection of over 60 aircraft plus rockets, missiles, engines and models. It is on a 120 acre site which includes a picnic area, car park areas, souvenir and model shop. Although the Museum contains a preponderance of aircraft, it is also noteworthy for its fine selection of German wartime rockets, including the V2 and Rheintochter.

The tour, beginning with a short Presentation at 1.45 pm, will be accompanied by a guide.

Registrants are expected to make their own arrangements for travel to Cosford. Trains run from Euston (change at Wolverhampton) and, on leaving Cosford Station, go under the railway bridge and follow the fence. The Saturday return fare is £17. An alternative way of travel is via National Express from Victoria Coach Station, from which further information should be obtained.

This will be a special afternoon tour, limited to 25 members. Registration details and further information available from the Society. Please enclose SAE.

6 July 1988, 7-9 pm **Lecture**

SUPERNOVA 1987A

A.T. Lawton

The discovery of Supernova 1987A last year caused great excitement amongst astronomers throughout the world. Although not visible in Britain or Europe many scientists have been involved in a series of international observations which are still going on. Astronomers now expect to see a pulsar in two to three years time, spinning at the rate of around 150 times a second.

Members only. Please apply for ticket, enclosing SAE, in good time.

14 July 1988, 10-4.30 **Symposium**

EXTENDING THE SPACE INFRASTRUCTURE

The reports of the National Commission on Space and Dr. Sally Ride have paved the way for a new innovative space policy in the United States. It encompasses the setting up of bases on the Moon and manned exploration of the planet Mars. The BIS is holding a two part symposium on the issues raised by this exciting new prospect.

The purpose of the symposium is to start European discussion on the subject, including a review of American proposals, and proposals for suitable European contributions to the programme.

The symposium covers the following subjects:

- Infrastructure planning
- Orbital transfer systems
- Geostationary operations
- Lunar transportation system
- Lunar bases
- Planetary exploration systems
- Exploitation of the solar system.

The first part of the symposium will be held on 14 July 1988 and the second part will be held on 15 November 1988.

Offers of Papers are invited
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Society. Please enclose SAE.

30 Sept – 2 October 1988 **Conference**

SPACE '88

Major weekend space conference, including varied programme of lectures and full social programme.

Venue: White Rock Theatre, Hastings, Sussex, UK

Registration
Forms and further details are available from the Society by sending 20p stamp or international reply coupon.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

VAT No. 239 1552 59

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Air Mail rates on request.

NEW

THE BRITISH INTERPLANETARY SOCIETY

The Society is pleased to introduce an exciting new range of exclusive BIS clothing and badges. As well as providing valuable publicity for the Society, all the garments are of high quality with proceeds going to the Development Fund.

All shirts (50% cotton 50% polyester) are machine washable.

Society Tie
Smart navy blue tie with Society rocket and stars motif

£6.00 (US $11)

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White T-shirt with blue Society logo

30/32, 34/36, 38/40, 42/44, 46/48, 48/50

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Small, Medium, Large, X/Large

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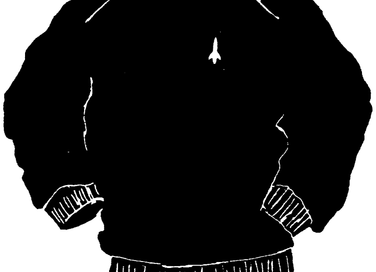

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Attractive navy blue Sweat shirt with Red Society logo.
30/32, 34/36, 38/40, 42/44, 46/48

£11.50 (US $21)

Casual Jackets
Versatile navy blue jacket with light blue Society logo. Showerproof, winter weight, with detachable sleeves for use as a body-warmer
Medium, Large, X/Large, XX/Large

£26.00 (US $47)

UK Space Policy

Lord Bessborough, formerly a Minister of State for aerospace, expresses his views on UK Space Policy in the wake of the House of Lord's Select Committee Report and its recommendations for increased expenditure on space by the UK Government.

Sir, I was fascinated to read the well researched UK Space Policy Report by the House of Lords' Select Committee on Science and Technology presided over by Lord Shackleton, and I agree with the principal recommendations in the Report. I have been discussing the future of space technology on and off with Lord Shackleton ever since the Lords debate on the subject in 1961. In the late 1950's and early 1960's there was, after Yuri Gagarin's flight and later when the Americans landed on the Moon, a glamorous aspect to space research and space exploration which has perhaps faded in recent years and especially since the tragic disaster of the American Space Shuttle. In 1970 as Minister of State responsible for aerospace I attended several meetings of the European Space Conference in Brussels and Washington when the idea of a European Space Agency was born and it is I suppose natural that I would, therefore, like us to continue to support the ESA.

I had the privilege recently of attending a meeting with the Prime Minister at which she gave entirely expected answers to most of the recommendations and conclusions in the Select Committee's Report. While I am well disposed to the conclusions and recommendations of the Report, I find it hard to contest the views of the Prime Minister and certain of her advisers that there may be no financial returns in the foreseeable future in respect of certain projects which I think most members of the Committee believe we should support – whether through the European Space Agency, the National Aeronautics and Space Administration (NASA) in the United States or on a national basis through the BNSC which the Committee thought the Government should continue to fund.

I also find it hard to contest the point that there does not appear to have been much willingness on the part of industry or financial institutions in this country to provide as much significant funding as one might have hoped for new initiatives having possible, yet uncertain, commercial prospects. I think especially of the ESA optional programmes.

Concerning Earth observations from space, I accept that the satellite and system manufacturing companies think that this area has potential involving, as it does, the capture of data by satellite, the processing of that data and its provision to end-users for a wide range of applications including weather forecasting. I also welcome along with Lord Shackleton the fact that the Government has agreed to the funding at around £4 million of an Earth station in this country to receive and process the data from ERS 1, the European Remote Sensing satellite which has already been very substantially funded by this country. To spend so much on this satellite and not be able to receive the data in this country would certainly have seemed curious. I also welcome the recent announcement that the Government have reconsidered the question of participation in the Polar Platform.

I appreciate the argument which some deploy that certain optional programmes may not perhaps be commercial activities in the immediate future and cannot be so unless a sure market is created by persuading end-users to pay for data which at the moment they expect to get free. I hope that the space industry will be prepared to make larger financial contributions in the development phases of the different projects cited in the Select Committee's Report. I regret that users do not at present show very much interest in putting money up front to pay for the data which the space community claims is so valuable to them and that in most cases they may rather expect Government to shoulder virtually the entire cost.

Reading the well researched articles in the April edition of ***Spaceflight*** on how to make space pay by renting satellites and on ESA targets in future commercial areas, I cannot help feeling we should be doing more in this country if we are not to fall far behind France, Germany, Italy and of course the United States, Japan and even China and India, in future High Tech applications and also if we are to stem the brain drain.

In this context I was, interested to read in *The Times* of March 12, 1988 the announcement that a consortium had been formed to build a launcher which could put satellites into low polar orbit at an acceptable cost and availability. I agree that such a launcher could certainly open up commercial potentials in space to countries which have so far been unable to afford to put up their own satellites. The consortium of European companies, which I gather includes at least two British firms and others from Norway and West Germany, would finance the whole venture with private capital.

I do recognise that there are competing demands for Government funds from other areas – I think particularly of superconductivity, biotechnology, molecular biology and genetic engineering, where we may see earlier returns. Nonetheless, I do feel that some extra Government funding in space would be desirable if we are to retain in this country the expertise among scientists and engineers concerned in this and other high-tech fields and prevent, in the Royal society's words, the brain drain from accelerating.

I was unhappy with the situation described in *The Times* of March 19, 1988 under the somewhat emotive headline "Britain loses out on £11 billion space station", saying that British firms would not benefit unless the Government were prepared to provide some additional expenditure, even if it were not as extensive as that of the French Government which provides seven or eight times more funding for ESA than we do. At least I would hope that HM Government, which is now in a happy economic position as a result of undoubtedly sound economic and fiscal policies over the last nine years, might be somewhat more generous in order to keep some of our best scientists from emigrating.

I well recognise that there are very substantial calls on Government resources in other industrial and scientific areas than space. Nonetheless, although half French, I would not like to see the French Government as the only large contributor in Europe in space activities. If this is not an irrelevance we are, I believe, in the words of the English Hymnal "dwellers all in time and space".

THE EARL OF BESSBOROUGH, DL
House of Lords.

Ed. *Lord Bessborough's letter is based on notes for a speech he prepared for the recent House of Lords Debate (**Spaceflight**, May 1988, p.182).*

Space Future in Jeopardy

Sir, I have read for some months the letters from readers lamenting the present Government's recent decisions on space funding, particularly for ESA projects. Having spent, before retirement, more than six years in the US space effort

and almost 15 years on communication satellites in ESTEC, the ESA laboratories in Holland, I feel that I can add some factual comments of my own.

I entirely agree with your correspondent E. M. Waine (*Spaceflight*, May 1988, p.220) that it will be impossible for young UK engineers to join ESA and gain a broader experience in the exciting world of space technology. This in fact would already seem to be happening as regards ESTEC, which is much the largest ESA facility. Using a monthly news-sheet from ESTEC that I receive, I note that 87 people joined ESTEC in the period November 1, 1987 to March 1, 1988; this includes a number of temporary personnel gaining experience in the young graduate, research fellow and similar categories. The breakdown by nationality is as follows:

France	31	Sweden	2
Italy	16	Netherlands	1
Germany	12	Switzerland	1
Spain	5	S. Ireland	1
Canada	5	Denmark	1
Austria	4	UK	0
Belgium	4		
Norway	4	Total	87

Turning to UK domestic affairs, successive Governments have concentrated on establishing a strong UK presence in the telecommunications field, as a counterbalance to German and French dominance in Spacelab, Ariane, etc. In March this year there was held in Arlington, Virginia, the 12th International Communication Satellite Systems Conference. In the 21 sessions, 125 papers were presented. Each session had two co-chairman, an American and a non-American, except for a NASA session and a military session with two US co-chairman each. The nationalities of the 19 non-American co-chairman at this prestigious conference were:

Japan	6
France	3
Italy	3
Germany	3
Canada	2
Belgium	1
UK	1
Total	19

Even within Europe, only one UK co-chairman was selected as against 10 others.

As regards the origins of the papers presented, the UK situation is slightly better, the breakdown being as follows when the UK figures are shown separately from Europe plus ESA:

USA including Comsat	64	UK	9
Japan	15	Canada, Australia	4
Intelsat	6	Eutelsat, Inmarsat	3
Europe (including ESA)	19	Origin not clear	5
		TOTAL	125

Nevertheless, it is hard to discern from the above data a strong UK overall presence in the very telecommunications field, that we have been led to believe is the one in which the UK has concentrated. The UK lead was established with the prime contractorships for OTS, the ECS satellites, the MARECS satellites, Olympus, the Inmarsat II satellites, and UK military satellites. How much longer is this situation likely to continue, with a diminished presence and influence in ESA, with less technical feedback from Europe, and with such limited representation at, and participation in, key conferences in this area?

Germany and France are now manufacturing their own TV and communication satellites and, very importantly , make the essential amplifiers for such spacecraft. Is another field of expertise, as occurred with launchers in the 1960's and 1970's, also to be left increasingly to the rest of Europe? Present indications leave very little scope for optimism. I have not even mentioned the field of manned space flight, where the UK, with unusual determination, seems to have set itself resolutely against any foreseeable future participation, in spite of the glamour that attracts some of the best engineers to this area.

DONALD H. HOWLE
Somerset, UK

Re-use Of Gemini 2

Sir, I am a new member of the BIS and would like to congratulate you on your fine publication and Society.

In the article *'Born Again'!* (*Spaceflight*, March 1988, p.93) Mr. Lorenz fails to mention a significant case of re-used spacecraft – that of Gemini 2. Although both of Gemini 2's missions were unmanned, it was certainly the first re-use of a manned (or man-rated) spacecraft.

The first flight of Gemini 2 occurred on February 19, 1965. It was a suborbital systems test. The spacecraft was a complete production Gemini craft, fitted with crew simulators in the ejection seats. These simulators tested the environmental and communications systems. The flight was a success.

Gemini 2's second mission was on November 3, 1966, as part of the Air Force's Manned Orbital Laboratory. The spacecraft was modified to include a hatch in the heatshield, allowing access to the MOL itself. The goals of the suborbital flight were to test the integrity of the modified heatshield and to prove the Titan IIIC launch vehicle. Both goals were fulfilled, but as events turned out, it was the first and only flight of MOL.

Does anyone know what Gemini 2's ultimate fate was?

Finally, at first I disbelieved that the Gemini EVA hatch was used in Skylab as mentioned by the author, but sure enough photos do show it there. Amazing!

PETER O. JOHNSON
New Hampshire, USA

Space Tethers

Sir, I would like to congratulate you for the excellent work that you have done with the layout and coloured graphics of the "Space Tethers" article published in the May 1988 issue of ***Spaceflight***. Unfortunately, my last name, Ionasecu (first author), was misspelled.

RODICA IONASESCU
California, USA

Ed. *Our apologies for this type-setting error and we take this opportunity to bring the correct spelling to our readers attention for future reference.*

Apollo Mission Tracking Stations

Sir, I have been collecting stamps, postcards and First Day Covers of the Apollo Space Missions for several years. I wish to add to this collection by adding details of the Earth Tracking Stations. Although I have seen several maps with the stations dotted about on them, I have not been able to find out their individual names. Can you help me with this matter?

VIVIAN P. HOLLAWAY
Essex, UK

Ed. *Between the start of Project Mercury in 1958 and the first Apollo Lunar landing in 1969, NASA built up a global tracking and communications network without which the entire Manned Space Flight Programme could not have functioned. An account of this development together with the names and locations of the stations may be found in the article 'Communications and Manned Space Flight – The Vital Link' by D.E.B. Wilkins published in the November 1987 issue of* **JBIS** *and obtainable from The British Interplanetary Society, priced £2.00.*

CORRESPONDENCE

Word Origin – Russlish

Sir, I was interested to read that the much respected originator of the word 'Russlish' (***Spaceflight***, May 1988, p.193) regards it with some misgivings.

I plead guilty as charged to lifting it straight out of *Odyssey Two*. The date on the inside cover of my personal copy tells me that I first encountered the word in March 1983, and I clearly remember thinking at the time how appropriate it was to my VHF Radio encounters with the cosmonauts. For while there have as yet been no lengthy multinational space missions and in spite of the "dog in a manger" road blocks of the CoCom variety, there is none the less a very real linguistic cross pollination taking place.

Russian speech is liberally sprinkled with words like normala, telescopa, radiotelegrapha, photographia, and in the reverse direction, thoroughly useful words like glasnos, sputnik and molniya, are in general use in the West.

I appreciate that this is not perhaps what the author meant when he denigrated the use of mixed Russian/English. None the less, I venture to suggest that it is a useful trend, given that the ten feature words of cosmonaut "speak" (panyeta, curashow, conyesti, spaceba, dubra outra, slowshum, niet, da, lad na, tak), plus the Russian numerals from ADEN to DVAD TSAT, and, knowing that half of the rest of the words they use have common Russian/English roots with similar phonetic pronunciation in either language. There is, therefore, no great difficulty in following at least some of the Russian coming down from space.

The world rewards the "doers" who break new ground, by using their word names. I hope English and Russian will continue to be enhanced and enlarged by borrowed words, although I would agree some caution is necessary, as when I was sure I heard the phrase "Printed Circuit Pagoda", and found myself wondering how the Russians managed to build Burmese Temples out of electronics hardware? Fortunately the dictionary rescued me by revealing that the root word pagoda = Taryóa, meant that the printed circuit was destroyed, ruined or broken!

J. BRANEGAN
Fife, Scotland

Colonising Space

Sir, I read with interest Gregory Matloff's article entitled 'Intergalactic Hitch Hiking' (***Spaceflight***, April 1988, p.174) which seemed primarily concerned with long duration manned comet and worldship missions as opposed to straight forward interstellar exploration.

Of course the whole topic of starflight will remain firmly in the realms of science fiction for a very long time, but nevertheless, there is plenty of scope for realistic speculation, as has been the case with the Daedalus study. While there can be no way of predicting accurately the course future society may take, I personally find it quite inconceivable that even a few hundred years from now anyone will consider the concepts of worldships as viable. Even a single world government would be hard pressed to justify the enormous expense involved, which would make projects like the building of the Panama Canal, or putting men on the Moon or Mars, seem like drops in the ocean.

Can we seriously expect society to ever finance the massive costs of transporting colonies of elitists on open-ended journeys into the unknown with no foreseeable chance of return on investment? In my opinion, it is also quite ludicrous to attempt any form of comparison with past human colonisation as suggested with the Polynesians. I find myself asking the question, why bother with worldships in the first place? Anyone wanting to colonise their stellar neighbourhood would be well advised to consider sending much smaller ships containing biological material which would be assembled at the destination. As I recall, Arthur C. Clarke's fictional worldship 'Rama', which was mentioned in the article, carried its passengers in this manner.

Perhaps more credible is the idea of establishing bases on or in comets and possibly being able to adjust or control their orbits around the Sun. Perhaps one day they might even be considered as tools for terraforming, but they nevertheless seem unlikely candidates for interstellar operations.

Before any serious attempts at interstellar colonisation can be proposed, there will be a need for very extensive and thorough surveys to be carried out by robot probes, returning their data from candidate star systems within a realistic time frame, which will mean high performance propulsive systems. Starship drives are obviously of key importance and may well operate on as yet unthought-of principles.

It is my belief that technology along the lines of fusion drives will in fact be the key to opening up the solar system within the next hundred or so years as opposed to colonising the stars.

W. P. ROSE
Norfolk, UK

Soviet Shuttle to be Unmanned

Sir, Photographs and news videos of the first Soviet Energia launch vechicle on its pad show the large service tower and swing access arms servicing the vehicle just prior to launch. The swing access arms appear to provide services (electrical power, propellants, communication lines) to Energia on the side 180 degrees from the 'payload carrier' and to the four side-mounted boosters only. The service tower location, which is offset from Energia's launch pad, and the angled geometry of the swing arms from this service tower would appear to make it difficult for the Soviets to supply on-pad services to any future manned shuttle vehicle that would be mounted in place of the payload carrier. Long distance television pictures of the 'Energia launch pad' did not reveal any sign of a possible mobile service gantry.

In view of this observation, I would suggest that the small, 30-ton Soviet shuttle that will be launched by Energia will be unmanned and will be prepared for flight before mounting onto Energia. This would support comments by Soviet Glavkosmos officials, who have noted that the Soviet small shuttle's first flight will be unmanned. It would further suggest that they have no immediate (next two to three years) plans for a manned version of this shuttle – except maybe, for return-from-orbit flight from Mir?

P. J. PARKER
Newcastle, Staffs, UK

Soviet Picture Puzzles

Sir, Pictures recently published in Soviet books have raised some interesting questions.

In [1] Soyuz T-13 is pictured in flight but several familiar features are missing from its exterior. It does not have a rendezvous antenna nor an active docking unit. These are visible on Soyuz T-2 on page 110 in the same publication. The missing antenna can be explained as T-13's mission was to visit the 'dead' Solyut-7. The station could not 'talk back' to Soyuz, so no rendezvous antenna was necessary. But what about the missing docking unit?

In another Soviet book [2], Valentina Tereshkova is shown wearing a Voskhod or early Soyuz flight suit. As Tereshkova left the Soviet Space Program soon after her Vostok-6 flight, can anyone explain this?

LUCIEN van den ABEELEN
The Netherlands

References

1. Glushko, *Razvitye Raketostroyeniye I Kosmonautiki USSR*, p.131.
2. *Perviye v Mirye*, p.127.

"The Muses Gave The Greeks Genius"

Sir, The above quotation was made with some degree of envy by the Roman poet and writer Horace (65-8 BC) when translating various already ancient documents from Greek to Latin.

The quotation is entirely justified when asking questions such as:

1. Who made the first measurements of the distance of the Earth from the Sun?
2. Who first measured the distance of the Earth from the Moon?
3. Who first proved the Earth was round?
4. Who realised the Moon influenced the tides?
5. Who was the first to realise that the Earth was NOT the centre of the Cosmos (the Greek word for Order apposed to Chaos).

The answer is that all the "who"s in these questions were Greek scholars and philosophers who were slowly ferreting out Nature's secrets. It might be argued that, if only such scholars had been left alone to develop their "universities" at Samos, Alexandria, Syracuse and other places where Greeks settled we would, by now, already be colonising nearby solar type stars.

The Roman Conquest of Greece (and the subsequent break-up of the Roman Empire) delayed the advance of scientific thought by nearly 1500 years!

As we approach the beginning of the 3rd millenium and look back nearly 1000 years to when Britain was about to be invaded, we can contemplate that if this invasion and further invasions had, instead, been replaced by a 'wave of knowledge' of the type experienced in the Renaissance but spreading from Greece not Middle Europe, and from 150 BC onwards not 1500 AD (i.e. 1650 years ahead of what actually happened), the result would have been 1650 years of art, technology and science and the BIS Daedalus Project might now have been flying over distances of 50 light years or more and carrying passengers out to new worlds.

Space flight is threatened by the same basic elements that killed off the thinking that was Greek in origin. We face exactly the same obstacles – lack of interest in "pure research", quick short-term profits, any disturbance to establishment ideas and self-interest.

Is not this a Greek Tragedy that we must ensure *never* happens again? Can we afford the luxury of another 1600 years of Dark Ages?

A.T. LAWTON
Goring, Sussex, UK

Soviet Flexibility

Sir, Reports of recent interviews with Soviet space officials suggest some new conclusions on the future of their space programme.

The Soviet Union would appear to design its space systems with flexibility, economy, simplicity and reliability in mind if the following propositions hold true: that the SL-16 and SL-17 (Energia) boosters use the same engines and first stages [1]; that these engines are intended to eventually be reusable [2]; that the SL-16 will gradually replace both the Proton and Soyuz boosters, as a 20 tonne payload low-Earth orbit/5 tonne geostationary orbit launcher for the former and a manned capsule launcher for the latter; and that the capability of the SL-17 to launch 20/30 tonne payloads into geostationary/lunar/planetary orbits will be enabled by use of the SL-16's cryogenic second stage as a strap-on third stage.

If such launch capabilities do emerge as true, then Soviet orbital systems will themselves become more capable. The 1995 100 tonne Mir 2 module will probably act as a command centre/logistics point/habitation base for many attached and free flying 20 tonne modules [3]. Such modules, which may be based on the two-element Cosmos 1686/Kvant design, could be fitted out as research, observation, materials processing, cargo/fuel or even personnel transport units. It even seems possible that the USSR may be developing a new 10 tonne ballistic re-entry crew capsule (possibly tested on the Cosmos 1871 and 1873 flights) for attachment to a 'space tug' service section, to be launched as a 20 tonne vehicle on the SL-16.

Such a 'Soyuz II' vehicle, if it does emerge, could carry personnel to the Mir 2 complex more safely than the Soviet automated shuttle on the larger and more complex SL-17. Attached to the space station it could act as an emergency Earth return vehicle or simply as an alternative to the shuttle. For though it seems the Soviet shuttle will be manned in 'several years' time [4], this perhaps may simply mean it will bring crews back to Earth, where its controlled landing capabilities will be safer than a capsule, and not launch with them aboard.

If such a large manned capsule does emerge in the next few years, it may find its first use in taking the first men into orbit, where perhaps it could dock with the Cosmos 1870 module for a maintenance and inspection mission.

PAUL J. MANT
East Sussex, UK

References

1 *Flight*, February 6, 1988, referring to the RD170 806 tonne engine
2. *Flight*, January 23, 1988, p 26
3 *Flight*, October 24, 1987, p.36
4 *Spaceflight*, May 1988, p 185.

Soyuz TM Retains Orbital Module

Sir, There is one aspect of the Russian Soyuz TM construction that I am surprised that no one has commented upon yet. I refer to the continued existence of the orbital module.

When the first Soyuz spacecraft were orbited we were informed that the orbital module was used to provide additional room for experiments and to house additional equipment for which there was no room in the descent module.

As the present role of the Soyuz TM is that of a space station transport, I would therefore have thought that the need for the orbital module would have ceased and it would have been cast aside in one of the spacecraft's up-gradings in favour of, for example, an extended crew compartment capable of carrying up to five cosmonauts. Have any of your correspondents any thoughts on the matter?

M.M. HUGHES
Northants, UK

Prospero Launch Photograph

Sir, Following the launch of "Prospero", the first and only all-British satellite, on October 28, 1971, I made numerous efforts to obtain a photograph of the event. I contacted various contractors and government departments without success. They all apologised for being unable to supply "Prospero" launch photographs, and instead sent me numerous photographs showing the unsuccessful Black Arrow launch in September 1970.

On at least two occasions, ***Spaceflight*** has published photographs purporting to show the "Prospero" launch (January 1972, front cover; and April 1986, p.158). In each case the lighting angles and shadows clearly show that photographs of the September 1970 launch have been used. This confusion may have arisen because the 1970 photographs appear to have been issued to the press in anticipation of the launch of "Prospero." One copy in my possession is clearly labelled: "Britain's Black Arrow will launch Prospero from Woomera, Australia."

It would therefore surprise me if ***Spaceflight*** readers (myself included) have ever seen a photograph of Britian's one and only satellite launch, which seems most ironic. Can you now remedy matters, albeit 16 years after the event? If the Society can trace a genuine "Prospero" launch photograph, it surely deserves pride of place in a future issue of ***Spaceflight***.

GEOFFREY BOWMAN
Belfast N. Ireland

BOOK NOTICES

Challenger – The Final Voyage

R.S. Lewis, Columbia University Press, 562 West 113 Street, New York, NY 10025, USA. 1988, 249 pp, $29.95.

The explosion of Challenger on mission 51L 73 seconds into its January 1986 flight was one of the most traumatic events of the space age. Shock waves were felt throughout the world at the loss of the seven crew members. The catastrophe not only jeapordises NASA's leading space project but opened questions into the future of the entire programme.

The author, a science journalist who has covered the American space programme for a quarter of a century, provides an in-depth account of the tragedy, including both its prelude and aftermath.

Besides recounting the many questions surrounding the flight, such as the cold weather on the launch morning and how it affected the craft, the pressure building up on NASA staff and the design flaws in the solid booster rocket that caused the explosion, the book also provides a substantial recapitulation of the subsequent Report by the Presidential Commission which investigated the disaster.

The book is full of photographs and diagrams to help explain the disaster. Much more than just a look-back to a sad occasion, it provides a sobering glance towards the new space era.

Europe's Future in Space: A Joint Policy Report

Associated Book Publishers (UK) Ltd., North Way, Andover, Hampshire, SP10 5BE, England. 1988 224pp, £9.95.

European space policy stands at the crossroads even though the exploitation of space will play an increasingly important role in its economic and political future. Europe has produced a solid record of achievements in space but has not yet developed the capability to match their potential.

There is fierce competition with the US and Japan to provide technology: at the same time, both the US and USSR are rapidly developing their military space programmes.

This report argues the importance of establishing European autonomy in space and of ensuring that the Europeans have the means to safeguard their own security interest in space. In the case of the UK, in particular, the effects of withdrawal from space involvement will all-too-soon undoubtedly have serious repercussions on its defence capabilities.

In Darkness Born: The Story of Star Formation

M. Cohen, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 1988, 196pp, £9.95.

Much new research on stellar formation has been carried out over the last decade yet, until recently, little of this has filtered through to a popular level.

The aim of this book is to bring together diverse work from many different fields of astronomy and to describe present ideas on the nature of our Galaxy and how stars are formed.

Basic concepts are used to develop a theoretical picture of how stars evolved from giant clouds of dust and gas and to describe observational studies of some of the different types of stars which is now being carried out.

The book adopts a very popular approach and is thus easy to read. It has no equations and demands little in the way of a pre-knowledge of physics from the reader.

Meteor Showers: A Descriptive Catalog

G.R. Kronk, Enslow Publishers Inc., Bloy St & Ramsey Ave., Box 777, Hillside, NJ 07205, USA. 1988, 291 pp, $24.50.

Meteors (or "shooting stars") have long attracted attention in the night sky, the earliest known shower being recorded by the Chinese in 1809 BC: the earliest European record occurred some time later, in 652 BC.

Most meteors are sporadic, i.e. seemingly coming from nowhere, flashing briefly into our view and then disappearing. The paths of others, although apparently moving at random, can be traced back to show that they come from a common point in the sky, the radiant. They are thus part of a shower, i.e. part of a stream of meteors spread out in a common orbit around the Sun and which, briefly, intersects the path of the Earth.

This book presents information on more than eighty visual meteor showers which recur annually, from the conspicuous Perseids (the "tears of St. Lawrence") to obscure showers poorly known to anyone other than specialists. For each shower the author gives the time and duration of maximum activity, brightness, orbital information and other interesting facts.

This compilation has been prepared on a month by month basis, with separate chapters for each month listing the particular showers likely to recur then.

At one time it was thought that a fair proportion of visual meteors came from space via hyperbolic orbits. We now know that this is not so: almost all meteors are non-icy solids that have been ejected from comets.

A Reference Catalogue and Atlas of Galactic Novae

H.W. Duerbeck, Kluwer Academic Publishers Group, P.O. Box 989, 3300 AZ Dordrecht, The Netherlands. 1987, 212pp, £34.00.

This volume, reprinted from *Space Science Reviews*, provides detailed information on all novae and novae-related stars observed in our Galaxy between the years 1670 and 1986. Each of the 277 entries includes a note on designation, type and details of discovery. Other information gives accurate positions, outburst data, bibliographic information on light curves, and spectroscopic observations including spectral regions outside the optical part of the spectrum, together with special features such as shells or other general properties.

The basis of the book was the evaluation of the large photographic plate collections and observations held in Chile and Spain. Its aim is to serve the astronomer in two ways. The first is to provide a concise compendium of information which lies otherwise scattered throughout the literature, as well as charts to help identify what are invariably faint telescopic objects. The second is to provide a considerable potential for further theoretical studies, for the listings and bibliographic references can be a most useful starting point for further statistical and other studies of novae.

Supernova Remnants and the Interstellar Medium

Ed. R.S. Roger and T.L. Landecker, Cambridge University Press, The Pitt Building, Trumpington Street, Cambridge, CB2 1RP, England. 1988, 540pp, £40.

The surge of interest triggered by the appearance of supernova 1987A makes this volume particularly welcome. The contributions are knowledgeable and extensive and cover both theory and observational results.

Supernovae and their remnants play a vital role in the evolution of a galactic disk both through injecting heavy elements and cosmic rays and by energising interstellar material.

The medium which surrounds each supernova determines the subsequent evolution of its remnants. This interaction between the supernovae and their remnants was the theme of IAU Colloquim 101 held in 1987 and now recorded in these Proceedings which collect together the twelve invited review papers and 81 contributed papers.

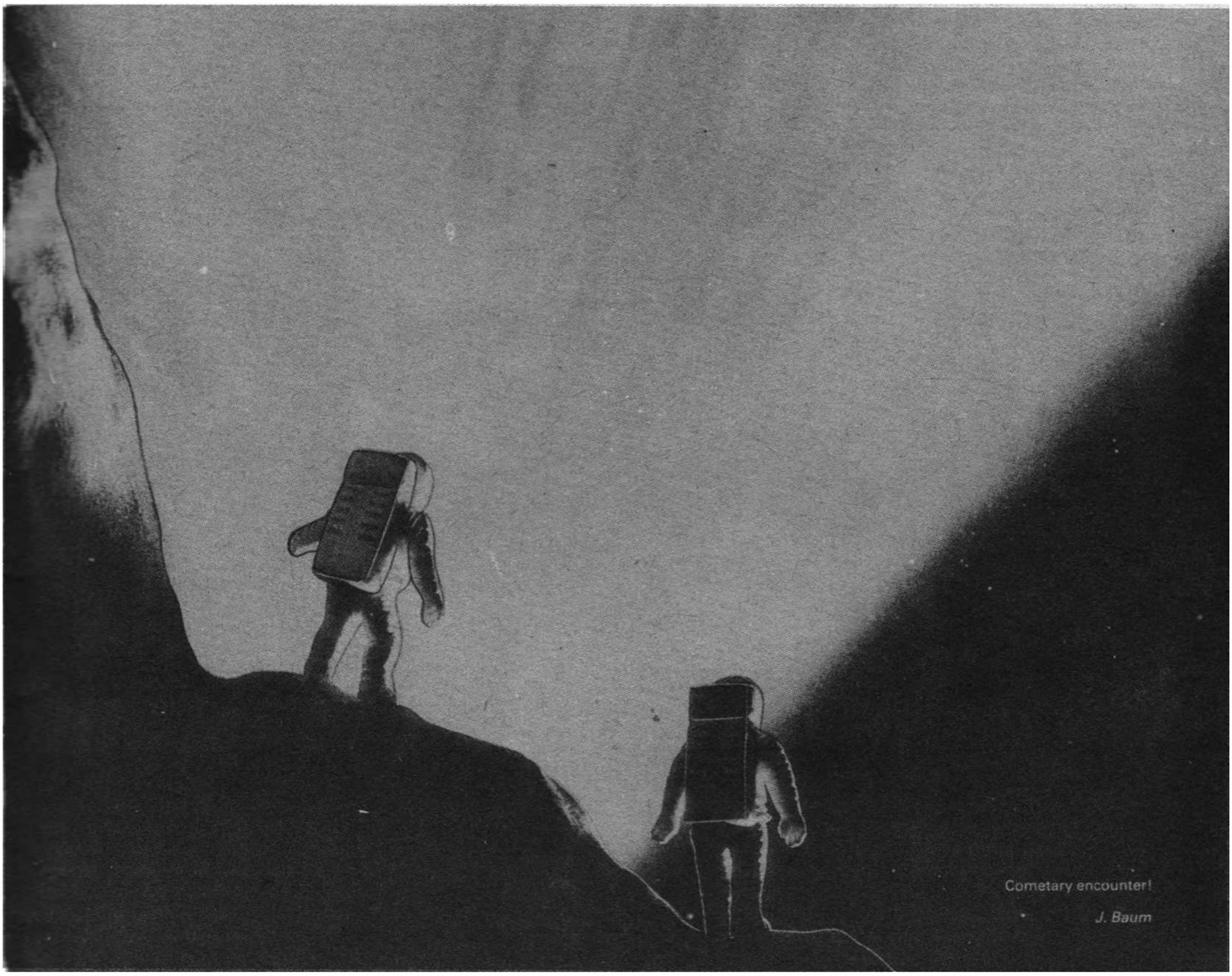
Remnants of galactic super novae are usually identified by their non-thermal radio spectra, relatively strong polarisation and shell-like structure. Many are observed as X-ray sources. About one third of those known appear in the data collected by the Infrared Astronomical Satellite (IRAS).

Physical Processes in Interstellar Clouds

Eds. G.E. Morfill & M. Scholer, D. Reidel Publishing Group, P.O. Box 989, 3300 AZ Dordrecht, The Netherlands. 1987, 554pp. £64.00.

This volume sets out to determine the current status, aims and future direction of research on interstellar clouds, summarising the latest observational results and moving from the global and large-scale to the finer details and dynamics, before progressing onwards to the processes, dynamical, chemical, electromagnetic and similar characteristics involved.

It thus provides an excellent overview of interstellar cloud physics with descriptions of practically all areas where advances are currently being made.



Rendezvous with a Comet

Throughout history, relations between humans and comets have been significant and diverse. One component of this association has been based upon awe: generated by the great spectacle presented by nature or, at times, by superstitious urgings. The scientific use of comets was dramatically demonstrated in the eighteenth century through Edmund Halley's application of the dynamical methods of Newton to the determination of cometary orbits (and the consequent identification of a certain series of cometary apparitions with the orbiting celestial object that now bears his name). The interaction of coma and tail with magnetic fields and the solar wind provides a gigantic laboratory for space physics. Recently, the expectation of links between cometary material and the primordial state of the solar system, including aspects of the origin of life, has further increased scientific interest in the exploration of these cold museums of initial conditions.

Although the proposed Comet Rendezvous Asteroid Flyby (CRAF) mission was not included in the President's budget as a fiscal year 1989 new start, CRAF enjoys strong support within NASA. The CRAF proposal has been strengthened by combining it with the Cassini mission to Saturn as a joint contender for a new start in fiscal year 1990.

The reasons for this bonding are both scientific and programmatic. A major objective of the Cassini mission (see the April 1986 edition of this column) is the exploration of Saturn's large satellite Titan, including traversal of its atmosphere with a probe. Investigations of this atmosphere are expected to yield information complementary to CRAF findings with respect to understanding the early solar system and the conditions under which life originated. Fiscal and engineering benefits are obtained through commonality of spacecraft design, parts buys, and testing; both spacecraft would belong to JPL's Mariner Mark II series which builds upon experience from earlier interplanetary spacecraft as reported in the April 1987 "Space at JPL".

With the delay of a year introduced for fiscal reasons, the existing mission design for CRAF had to be evaluated for suitability and modified as necessary. Sylvia L. Miller has been the Mission Design Engineer for CRAF since October 1983. Prior to that she played a lead role in the design and implementation of the all-sky survey of the Infrared Astronomical Satellite (IRAS); see the January 1984 "Space at JPL" for Miller's (*née* Lundy) work during IRAS operations. She outlined the mission modifications that are underway for CRAF.

The first step was selection of a comet with which to conduct a rendezvous. The previous plan, consistent with a February 1993 launch, was to encounter Comet Tempel 2 in October 1996 and accompany it along its trek to perihelion (closest approach to the Sun) 1036 days later. The new plan is to explore Comet Wild 2 after launching with a Titan IV/Centaur G' combination and arriving at the comet in February 2001, 950 days before perihelion.

The selection of Wild 2 as the new target for rendezvous began with inspection of the list of backup-mission comets that had been developed as part of the Tempel 2 mission design. Judgement by the Project Science Group of the scientific merits of each comet was combined with trajectory options that were consistent with spacecraft and launch-vehicle constraints. A key mission consideration is the number of days before perihelion that the spacecraft can be delivered to the comet. It is desirable to reach the comet when it is far from the Sun so that observations can be conducted through a full cometary-development cycle: from quiescence to the full production of gas and dust occurring near perihelion.

To reach the comet, the usual litany of trajectory types was examined – various sequences of gravity assists from Earth and/or Venus melded with appropriate firings of the spacecraft's engine in deep space. Miller said that even Mars was checked for the possibility of furnishing a gravity assist, as small as that planet is (several years ago, an earlier mission design for the Galileo flight to Jupiter had planned to employ Mars in this capacity). The category that has been chosen is a so-called VEEGA type, the same type to be used by Galileo after its October 1989 launch. The VEEGA class is explained by disassembly of the acronym: Venus (V) Earth (E) Earth (E) gravity assist (GA).

Trajectory selection is influenced not only by scientific objectives and planetary geometry but also by spacecraft properties: particularly the two attributes of total mass and propulsion capability. The former quantity is a major factor in determining the energy that must be supplied by the launch vehicle and onboard propulsive system; for the latter quantity, "more is better" is the general rule.

The total mass of the Mariner Mark II spacecraft will be approximately 5000 kg at injection into interplanetary space. About two thirds of this mass is propellant which can be utilised to alter the speed of the spacecraft by more than 3 km/s during the life of the mission. The propulsion subsystem will be supplied by the Federal Republic of Germany. One third of the mass, about 1600 kg, is devoted to scientific payload and engineering structures (the Voyager spacecraft, at approximately 800 kg, is one half of the mass of its more capable descendent).

Two areas of on-going research within the framework of the basic trajectory plan are launch-period analyses and asteroid flyby studies. For obvious reasons it is necessary to plan for more than one day to put a vehicle into space: the launch period (of course, there is also a daily window for launch). The minimum desired launch period for CRAF is 10 days and Miller's team is currently seeking to understand the effects on onboard propellant margins and trajectory characteristics as one moves from the optimal launch date. The path resulting from a launch on the first day of this 10-day period has been designated as the "baseline trajectory" and is employed by all elements of the project as a standard against which to perform navigation, telecommunications, thermal and other studies.

The asteroid which CRAF plans to engage is Iris, an object with a radius of 102 km and similar in composition to the stony meteorites collected on Earth. Flyby speed is calculated to be 19.7 km/s at a range of 100 asteroid radii. Asteroid selection is coupled to launch-period analysis and studies will be done to determine the effects on launch-period length and position by choosing asteroids other than (or in addition to) Iris.

The exploration of the comet can be subdivided into three mission phases which are, in chronological order, (1) approach and initial characterisation, (2) near-nucleus science, and (3) perihelion investigations.

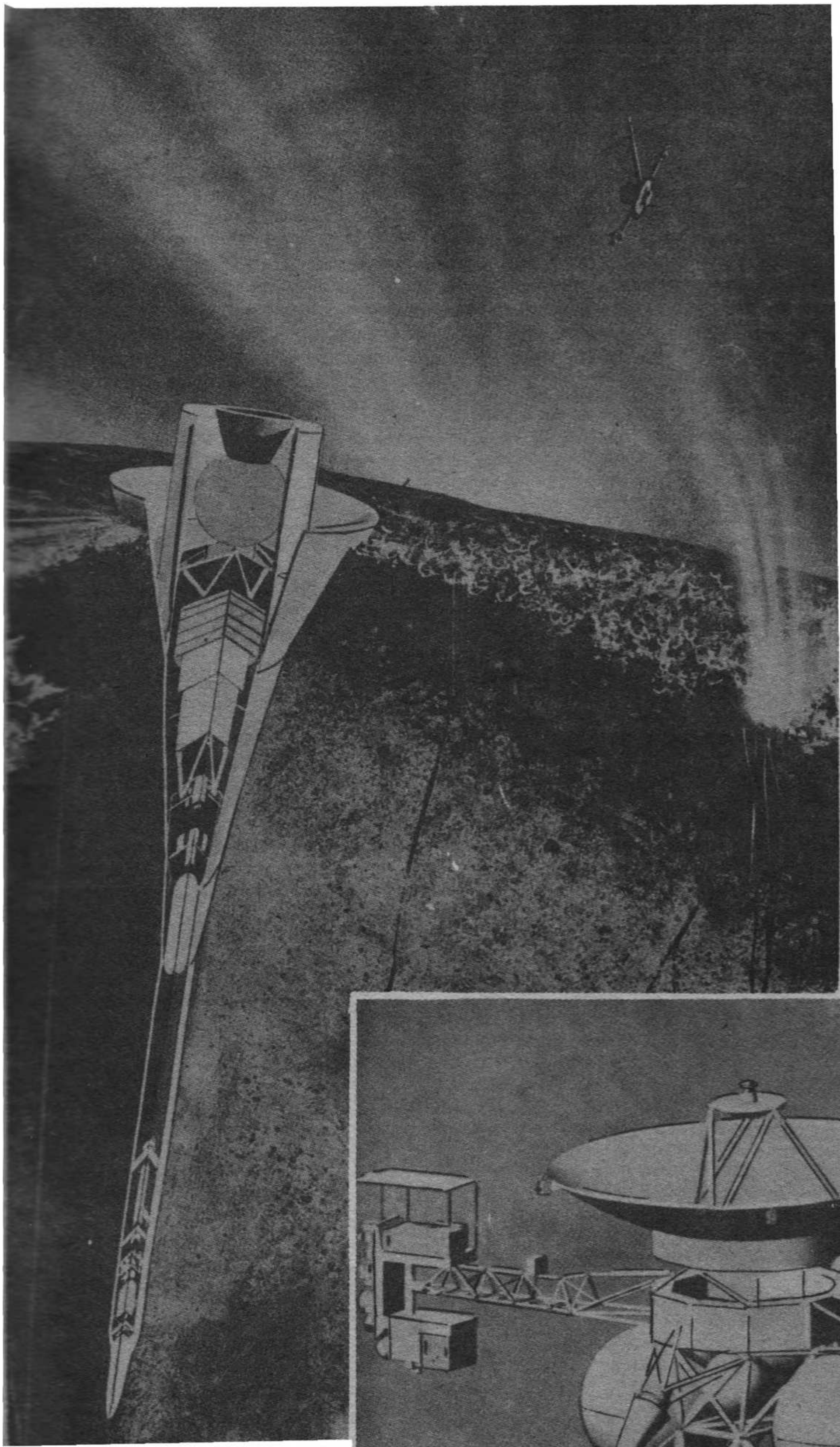
Approach to Wild 2 will be from the Sun side to facilitate observations and optical navigation. Fifty days will be spent in moving from 200,000 km distance, after arrival in February 2001, to a range of 5,000 km in order to begin gross characterisation – size, shape, rotation rate, pole location, and the nature and location of potential hazards.

Near-nucleus science commences at an approach distance of about 100 km. In addition to scientific observations, it is important to determine early the mass and higher-order properties of the gravitational field of the comet to enable navigation near this small and probably irregularly shaped object. With initial flybys, the mass can be estimated with an accuracy of 10 to 20 per cent. Then, the spacecraft will enter into orbit about the nucleus, and after two revolutions the cometary mass should be known to an accuracy of one per cent. Two-week orbits are used for planning purposes; the corresponding distance from the comet should be in the range of 40 to 70 km, depending upon the actual mass of Wild 2. Eight subsequent orbits within 10 cometary radii – Wild 2 may be about 3 km in radius, but this quantity will not really be known until observations from CRAF – will provide data on the higher-order properties of the gravitational field.

At approximately one year after rendezvous, a penetrator, perhaps two, will be fired into the nucleus. Miller said that a current activity in mission design is to develop a catalogue of possible orbits about the comet's nucleus that could support the relay of data from the penetrator to the spacecraft and thence to Earth.

The concern centres about the desire not to constrain the selection of the site of penetrator insertion by telecommunications considerations. The data system onboard the penetrator includes a memory buffer which must be emptied every 10 hours or less in order to avoid loss of data. The design of periodic orbits to overfly arbitrary regions on the surface of a rotating nucleus is complicated by the almost complete lack of knowledge of cometary parameters: gravitational field, size, orientation of spin axis and rate of rotation. Of course, these quantities will be well known at the time of penetrator release; the challenge now is to show that, within reasonable limits on parameters for the nucleus, a large fraction of the surface will be available for placement of the penetrator. The device will take data for 10 days with its 1.5 m long spike-like body piercing the crust and sampling the pristine ices that lie beneath this cover.

Near-nucleus science will also be conducted from the spacecraft utilising a comprehensive set of instruments

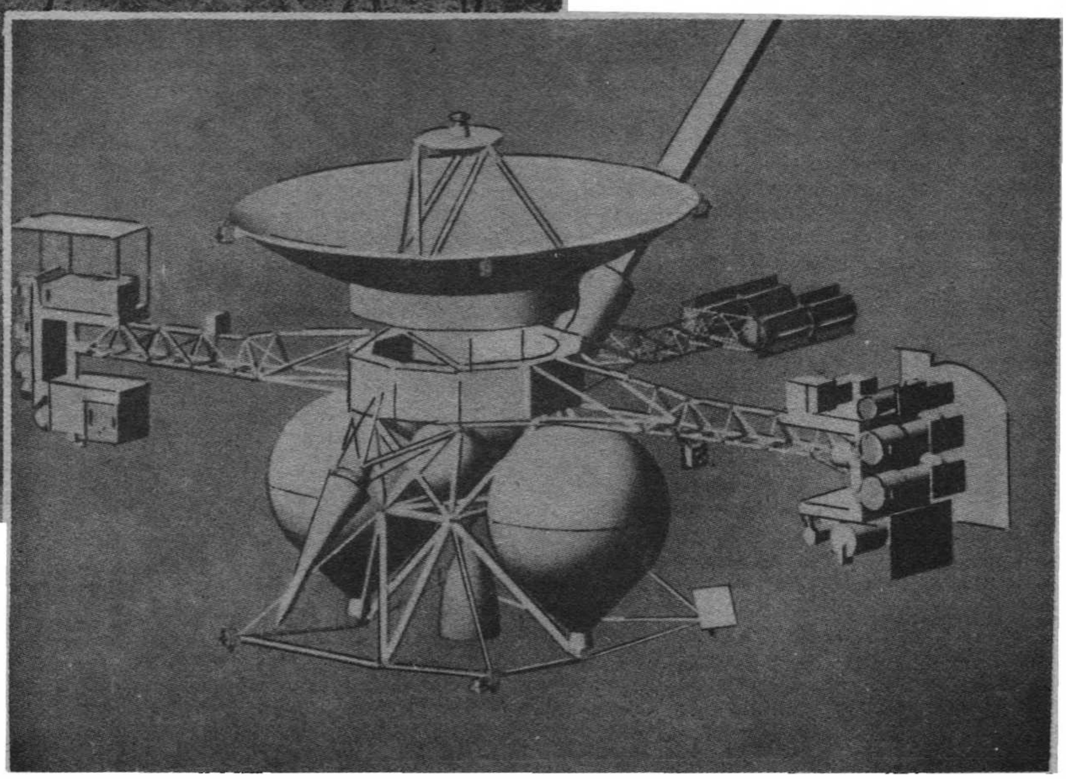


(see the February 1987 edition of this column for a payload synopsis). The Thermal and Infrared Experiment (TIREX) will be used to produce a thermal map of the nucleus, an aid of particular value for penetrator site selection, while a visual map will be the product of the two cameras, narrow and wide angle.

As the comet approaches closer to the Sun, the perihelion phase of the mission will begin with the gradual withdrawal of the spacecraft from the awakening nucleus to a range of two or three thousand kilometres. Occasional forays within 100 km of the nucleus will be made to collect dust. At these times it will be necessary to close shutters on certain of the instruments for the purpose of avoiding damage.

Twenty days after perihelion an 80-day excursion 60,000 km down the tail (and return) permits close observations of this important feature in the anatomy of a comet.

Relatively little is known about Wild 2; it has only been observed at two previous apparitions, in 1978 and 1984. In an orbit with a period of 6.4 years, it swings between 1.6 AU and 5.3 AU of the Sun (an AU or "astronomical unit" is the distance from Sun to Earth, about 150 million kilometres) and is only inclined 3.2 degrees to the Earth's orbit. Observations at its next apparition in 1990 will be made by astronomers to derive further characterisation of the scientific properties of Wild 2. But imagine the far greater leap in knowledge a decade later as a camera of CRAF records the detailed mechanisms of an apparition while jets of gas and dust issue from the well-mapped nucleus, wrapping it in the fuzzy coma we see from Earth.



In this artist's conception (above), the Penetrator from CRAF has been fired into the nucleus of Comet Wild 2 in order to conduct *in situ* analyses of this object (the CRAF spacecraft shown in the background is of an older design than the current formulation of this vehicle). *NASA/JPL*

The spacecraft (right) for the proposed Comet Rendezvous Asteroid Flyby (CRAF) mission. *NASA/JPL*

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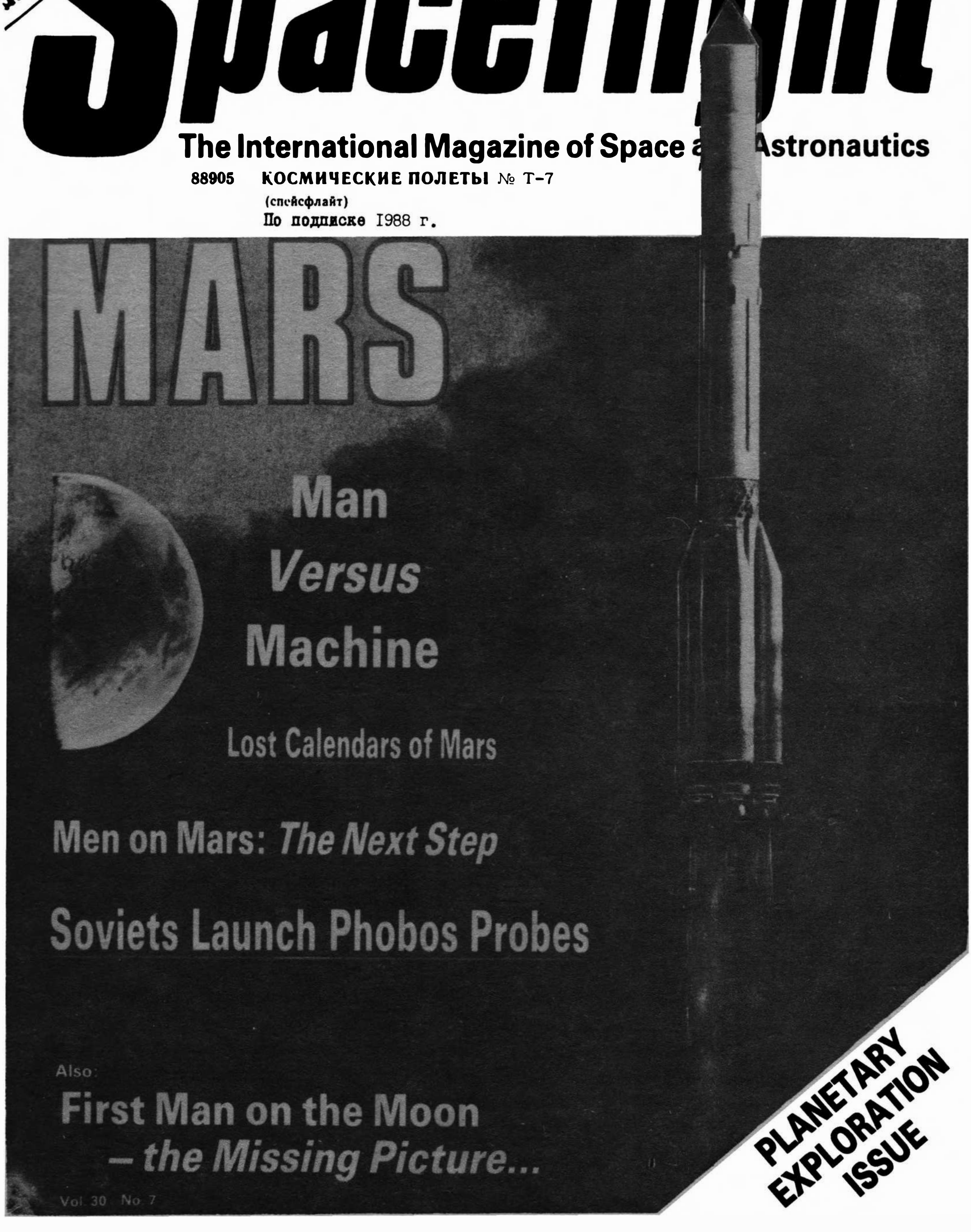

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Front Cover: A Proton rocket launch. This vehicle will be used this month (July) to send the Soviet Phobos probes on their exciting mission to Mars and its moons. Our special report on Mars begins overleaf and project Phobos is covered in a detailed article by ***Neville Kidger*** beginning on p.272

Man on Mars: The Next Step

by Robert C. Parkinson

The first man on Mars is probably alive today. But is a very expensive manned mission to Mars really needed? Robot spacecraft like Viking were tremendously effective, and cost far less. Would a manned Mars mission be simply a prestige project?

Perhaps not. Apollo missions were the key to the planetary missions of the seventies. The precursor spacecraft – Ranger and Surveyor – developed the technology for Mariner, Viking and Voyager. And manned expeditions allowed us to judge the effectiveness of those robot explorers. For the first time we had a detailed geology of another world and saw the outline of questions we needed to ask elsewhere. A manned survey of Mars might be equally rewarding.

Look at it another way. The lack of Mars missions since Viking is a matter of economics rather than interest. At the moment there exist proposals for:

- A Mars orbiting geological and meteorological survey.
- A Mars rover.
- A remotely piloted Mars aircraft.
- A sub-surface "penetrator" probe, capable of digging several metres below the surface of Mars to get a look at its internal geology.
- Surface sample return missions, capable of launching a kilogramme or two of "Mars dust" back to Earth for analysis.
- A mission to the edge of one of the Martian icecaps, looking for the effects of melting ice on the soil. (There are three or four other interesting areas the scientists would like a close look at as well).
- A sample return mission from one of the Martian satellites, thought to be captured asteroids, to return material which may date from the time of the planets' formation.

Viking cost about $400 million a shot. Would a manned mission capable of carrying out all these tasks and more be worth ten times as much?

Opportunities to visit Mars come at intervals of 25 or 26 months. Werner von Braun in 1952 proposed a minimum energy mission which would have travelled halfway round the Sun between leaving Earth and reaching Mars, and then waited 440 days at Mars while the planets rearranged themselves before starting an equally long, 260 day swing back to Earth. This is called a Conjunction Class mission.

There is a faster possibility. We can launch somewhat before Earth overtakes Mars in its orbit, stay for a very short time at Mars, and then return as the Earth moves ahead of Mars. Such Opposition Class missions are short, but energy demanding.

However, in 1963, R.L. Shon and W.M. Hollister independently discoverd a class of round-trip orbits using a Venus swing-by on either the outbound or inbound legs to reduce both flight times and energy requirements. The first missions to Mars will probably choose such an orbit.

Even for a particular type of mission, the energy requirements are not constant. Mis-matches in the orbits of Earth and Mars make some opportunities easier than others; 1985 would have been easy and 1990's missions would have been more difficult, but by the early 2000's the match will be growing easier again.

A second factor which affects planning is sunspot activity. The Sun goes through an 11 year cycle of high and low activity. With the extended flight times required to visit Mars, the risk of exposing the astronauts to large amounts of radiation from a "solar storm" becomes significant at times of high solar activity. A 1995 flight would have been at a time of "quiet Sun" and the next such period will occur about 2006.

How much will a manned expedition cost? Values as high as $70 billion have been quoted. But we have to be careful. That value comes from a Douglas Aircraft Company study of 1965, and includes development of all the required transport infrastructure needed for manned interplanetary exploration. For that price you get the Space Shuttle, the Space Station and a base on the Moon.

By the opening decade of the 21st Century most of that will be in place so the real cost, the cost of developing and building "mission specific" vehicles and hardware, will be modest. It is perhaps half that to develop and build the Initial Operating Space Station. Follow-on expeditions would be even cheaper.

By the 21st Century a Mars mission may not depend solely on chemically fuelled vehicles. Other developments may have by-passed such an approach. But the fact that it can be done, and done for a modest price, is important. Space enthusiasts have always believed that, given the right circumstances, it should be cheaper to send men than to try to do the same thing with dozens of robot craft.

Nevertheless, the mission is not simply people replacing robots. It is a proper balance of men and machines. For example, an expedition may carry three surface sample return probes, six "penetrators" and two Venus entry probes as well as a small communications satellite. In a very real sense the robots would out number the human crew.

Neither will the first expedition to Mars be the last. Predicting the shape of successor missions is even more difficult than predicting the first, but there are some factors which appear to be important.

First, a re-run of the first mission will cost perhaps only 25 per cent of the first. This is not only because we do not have recurring development costs, we can actually re-use some of the hardware. Unlike Apollo missions, which were launched at two monthly intervals, opportunities for a mission to Mars are limited. "Windows" for Mars recur only at intervals of two years. The commitment required for a Mars mission is therefore significantly greater than for an expedition to the Moon.

Secondly, the optimum date for departure from Mars orbit to home is actually slightly earlier than the optimum date for arrival from Earth. If we waited long enough, we could wait for the optimum "return window" in the next two year cycle.

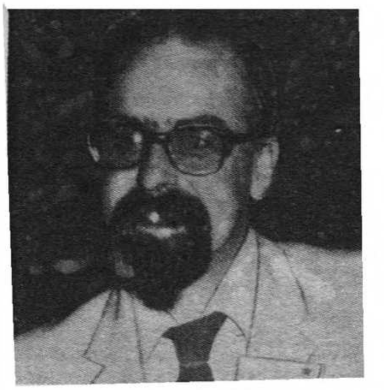
In fact we could abandon the Venus swing-by and go to lower energy direct transfers each way as proposed by von Braun in 1952.

Four hundred and forty days on

The above article is based on an extract from the recently published book by *Dr. Robert C. Parkinson*, 'Citizens of the Sky', in which he sets out his personal view of the future of space flight.

Dr. Parkinson, a Fellow of the British Interplanetary Society and employed at British Aerospace, was co-inventor of Hotol and is currently manager of the company's Future Launch Systems.

'Citizens of the Sky' can be ordered direct from the publisher at the special price to readers of *Spaceflight* of £12.75 (normal price £14.95), including postage and packing. Orders should be sent to: Dept SF 1, 2100 Ltd., 10 Silver Birch Avenue, Stotfold, Herts, SG5 4AR, England, enclosing a cheque etc payable to 2100 Ltd.



Mars is a long time for a first flight, but for a properly equipped second expedition it would give plenty of time for exploration on the surface. Indeed, such durations are typical of the time away from home expected by Antarctic explorers.

The US National Commission on Space suggested that transport between Earth and Mars might be significantly improved by having a "cycling spaceship" or station permanently shuttling back and forth between Mars and the Earth.

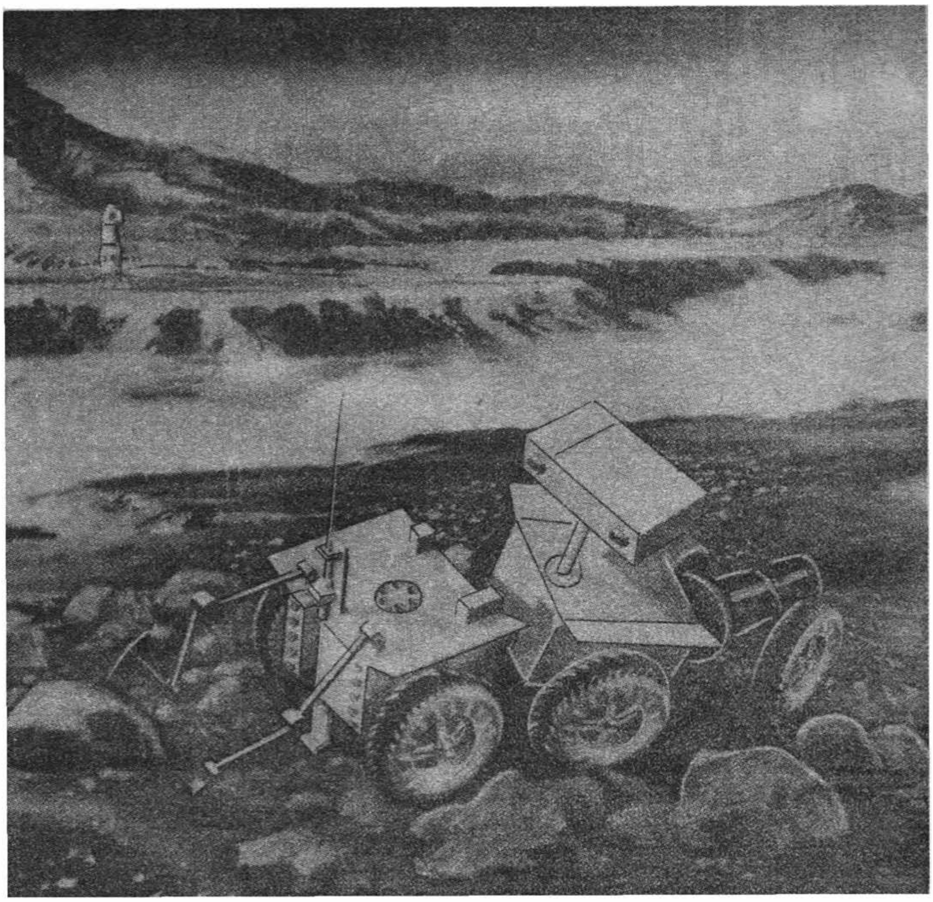
The advantage of such permanent bases would be that all the heavy life support equipment and structure to provide for the passengers over a six month trip to Mars would not need to be accelerated and decelerated at each end of the journey. Instead a small, cramped shuttle craft would carry passengers and stores between Earth orbit and the cycling station at one end, and the cycling station and Mars orbit at the other.

The cycling station itself would use gravitational "swing-by" trajectories at both Earth and Mars to maintain a steady link between the two planets despite their changing positions. The cycling station would provide its passengers with the necessities and comforts needed for their extended journeys, including "artifical gravity" by rotating the station modules on the ends of a long tether about their mutual centre-of-gravity.

A third important factor encouraging a succession of flights to Mars after the first is the growing probability that there is water on Mars, locked up in subsurface ice. A properly provisioned crew, with appropriate equipment and a suitable solar or nuclear power generator, would be able to manufacture their own oxygen and hydrogen propellants on Mars. That would save not only on transported mass, but would mean that the expedition could abandon the use of expendable Landers, using instead a recoverable surface-to-orbit "shuttle" for many flights. Single-stage, rocket-powered shuttle craft are relatively easy to design for the weak gravity of Mars.

In the second decade of the 21st Century, therefore, we can expect to see semi-permanent long-stay expeditions on Mars, generating their own propellants on site for ground-to-orbit propulsion. They could use ground or air transport to range long distances over the Martian landscape.

Martian aircraft are interesting, demanding high aerodynamic performance to fly in the thin Martian atmosphere, and would probably look like high altitude research aircraft being designed today. The explorers would use techniques borrowed from the growing Lunar Base to be self-supporting, perhaps even growing part of their own food supply. And, if the economics were favourable, every two years one exploration crew would exchange with the next.



A rover collects samples on the surface of Mars in this depiction by artist Ken Hodges In the background is the ascent vehicle. *NASA*

The case for a permanent "colony" on Mars is less immediately obvious than for the Moon, there are commercial prospects for the Moon today. Until we have explored Mars more thoroughly the economic prospects for Mars are less obvious. Indeed, Mars may have a long period like the Antarctic, where human occupation is for scientific purposes alone and the long term potential as a natural resource is recognised but not exploited.

Even so, the pressures are to make such a Mars Base a permanent facility capable of supporting its own operations. The true, permanent Mars colony may only arise as other space operations develop a demand for resources which Mars is particularly suited to provide.

An established "Mars Survey" may even be a socially desirable institution, providing a focus for a horizon beyond Earth and a source of international cooperation without competition, generating beneficial technology developments back home. That is one of the arguments in favour of "pure science", and a Mars survey could be a good example.

Soviets Plan Mars Missions

Soviet scientists have outlined a tentative ten to 15 year programme of unmanned Mars exploration – culminating in a 1998 sample return mission.

Dr. Valeriy Barsukov, director of the Vernadsky Institute for Geochemistry and Analytical Chemistry, says plans being discussed to follow on from the Phobos mission include a balloon to skip over the surface in 1992 and a rover/sample return vehicle in 1994. He said samples could be returned to Earth by 1996 or 1998.

When asked if the Soviets planned a manned Mars mission, Barsukov hedged, noting that such a journey would take a round trip of two and a half to three years.

"When our cosmonauts have flown around the Earth for three years, then let's decide whether to fly to Mars," he said.

The 1992 mission would send a double-shelled balloon, the inner shell filled with helium and the outer with carbon dioxide, armed with a mechanism to penetrate the soil.

The next mission would send robot "moles" that could penetrate the Martian surface 20 to 30 metres, perform chemical soil analysis and search for biological activity.

The final mission in the sequence would send a more sophisticated rover to collect soil samples and a spacecraft to return the samples to Earth.

The Search For Life

An unmanned rover collects samples of surface material in this painting of the Martian landscape by Ron Miller. © R. Miller

In this personal view *David H. Hinson* argues that we should not let our thoughts become polarised by the debate over manned versus unmanned missions In the final analysis it may be that a combination of the two is preferable to either alone.

Man Versus Machine

It is not before time that we are returning to Mars. More than a decade has passed since the US Viking landings without any kind of successor mission and this inspite of the fact that the Viking results did not even rule out the possibility of life at the landing sites, much less over the entire planet.

Indeed, two out of the three biology experiments gave a "positive" result. The prospect for life on Mars appeared very good until chemical analysis of the soil found no measurable organic matter. This was a great surprise, since some organics should have been deposited by meteorites, even in the absence of life. However, the chemical analysis was a thousand times less sensitive than the biology experiments.

In light of the Viking results, there has been a tendency to downgrade the search for life as a Mars mission objective. This is a great mistake. Exobiology should be a primary objective of some missions, and all landers should be sterilised until we know more about Mars than we do now.

There are several major types of proposed unmanned missions. Some are not designed to look for life but since they would tell us more about Mars, they have an indirect value in the search for life. However, only mobile rovers and sample return missions have a direct bearing on exobiology.

A vast variety of rovers have been proposed in recent years, including tracked vehicles, "beachball" vehicles blown by the Martian winds, and even aircraft. It is hard to say if any of these would be of any great use in looking for life. A rover may come across the remains of some Martian organisms. On the other hand, much of its mass could be devoted to making it move, leaving less available for scientific instruments. Microscopic life might not be obvious at any particular site, and an under-equipped rover could easily miss it.

By far the best way to search for microscopic life would be to bring a sample back to Earth, where a whole range of testing could be available. Such an investigation would be much more flexible and comprehensive than one using a small automated laboratory millions of miles from the nearest technician.

One US proposal for a sample return mission would require two space shuttle launches to put the spacecraft and its booster into Earth orbit. About a pound of Martian soil would be returned at a present-day cost of $2 billion or more.

However, such a mission poses many problems. The most fundamental involves preserving the sample to avoid any life present "dying" during its long journey to Earth – it may prove very difficult to provide a simulated Martian environment.

A second major problem is the chance that Martian microbes could cause disease in man. Although a very remote possibility, it is something that should be considered seriously.

A manned landing on Mars potentially solves both these problems. First, while material would be carried back to Earth, there could be moderately extensive scientific facilities on-board with trained astronauts/scientists on the spot. Second, if a microbe did cause disease in man, it is likely this could be detected before the expedition returned to Earth.

However, a manned landing raises many more problems of its own. First, contamination of the Martian environment would be almost inevitable as a result of astronaut EVA activity. It would certainly be wise to obtain some pristine samples before men ever landed on Mars.

Second, a manned landing will be very expensive. The cost would be a major burden for either the United States or the Soviet Union. A multi-national mission would improve matters, but even so can vast sums of money be justified? Much remains to be done in Earth orbit, on the Moon, and on near-Earth asteroids. Not only is this work of scientific importance, but it may also have an economic benefit that Mars will not bring in the near future. There is nothing to be shipped from Mars that cannot be more easily obtained from the Earth, Moon or near-Earth asteroids.

Only the study of extraterrestial life can justify an early landing on Mars. We could learn much about life in general if we could look at some organism that did not share a common origin with us. It would be worth almost any price.

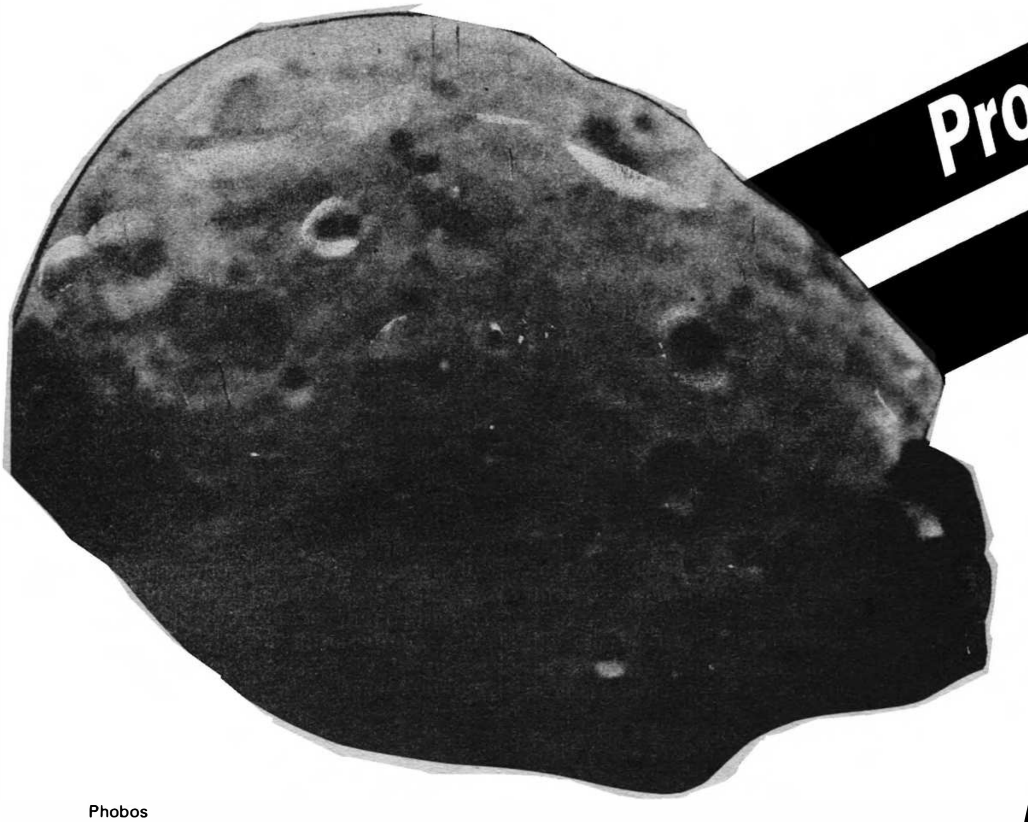
So we find ourselves in a bind. Only the study of life on Mars would justify a manned landing, while a manned landing has by far the best hope of finding life. We therefore need to re-examine the situation and design a mission that maximises the chance of finding life while minimising the cost. To do this, we need to get away from the idea of manned missions versus unmanned missions and consider a hybrid approach. Can we get all the advantages of each type and none of the disadvantages?

Not quite, but we can come close. Imagine a sample return mission where the unmanned lander docks with a manned spacecraft waiting in Mars orbit. In such a scenario much of the flexibility associated with men on Mars is lost, but it does prevent contamination of Mars and there would be researchers with facilities to examine at least part of the sample while still "fresh".

Many of the technical problems in placing men on the surface need not be resolved so this type of mission would be cheaper than a manned landing. If a manned vehicle goes into orbit about Mars it would mass less than half as much in Earth orbit as a vehicle carrying a manned lander. But why should the manned vehicle go into orbit about Mars? A manned fly-by craft for instance, would have only half the launch mass of an orbital one.

An orbiter has some advantages: a sample return vehicle can carry more payload into orbit about Mars than to Martian escape velocity and the orbiter could also visit the Martian moons Phobos and Deimos, both interesting in their own right and as sources of fuel and supplies for future missions. However, the fly-by approach is so much cheaper that it might be preferred for the first mission. Also, along with samples from several parts of Mars, a sample from one of the moons could be returned by the fly-by craft.

A Martian dust-storm threatens the safety of two human explorers (right) in a dramatic painting by US artist Ron Miller. R. Miller



Phobos

Project Phobos

A Bold Soviet Mission

The Soviets are set to resume their efforts to explore Mars after a hiatus that will have lasted a decade-and-a-half since their last and only successful Martian probe, Mars 5.

This month on July 7 and 12 two Proton carrier rockets will loft an identical pair of new generation Soviet probes to head towards Mars and its moons, Phobos and Deimos. The probes will actively examine the surface of the larger moon, Phobos, and so the Soviets have named the missions after that moon rather than continue the *Mars* designation.

Furthermore, the project has been the subject of large-scale international participation both in data analysis and hardware design and fabrication. The Phobos probes to Mars promise to be truly spectacular and clearly the Soviets are hoping to reap huge scientific and prestige gains from the project.

The main aims of the Phobos project cover the following:

- Remote sensing of the Martian surface and atmosphere in the visible, ultraviolet (UV), infrared (IR) and gamma-ray bands to determine the profile of the atmosphere, its chemical composition, seasonal variations and climate in relation to geological regions.
- Rendezvous with the moon Phobos to obtain data on its surface and interior by means of TV, IR imaging, radar sounding, laser and ion beam, chemical and isotopic analysis.
- Imaging of the Sun in the X-ray, UV and visible wavelengths. These studies, together with Earth-based observations, will allow for the first time three-dimensional stereoscopic studies of the structure of the solar chromosphere and corona.
- Studies of the interplanetary medium including the composition of the solar wind, the spectra and anisotropy of solar cosmic rays, interplanetary shockwaves and solar and cosmic gamma-bursts.

by Neville Kidger

International Cooperation

The Phobos project is international in scope. By mid 1985, after the initial announcement and details of the mission were known, more than a dozen countries and organisations had committed themselves to the project.

These were Austria, Bulgaria, German Democratic Republic, Hungary, Ireland, Poland, France, West Germany, Czhechoslovakia, Switzerland, Sweden and the European Space Agency. The UK is not providing any hardware for the project but data analysis will be done with the help of three British investigators.

In all there are 31 experiments on the spacecraft and the complexity of the international cooperation in the project is illustrated by the Sled experiment which uses instruments to study the peculiarities of the solar wind's interaction with Mars and will search for belts of particles trapped in the magnetic field of the planet, similar to the Earth's Van Allen belts.

The two 1.55 kg Sled instruments, which have two semiconductor telescopes in them, were fabricated in Ireland in collaboration with the Max Planck Institute in West Germany, the Central Institute for Physics in Hungary and the Space Research Institute in Moscow. After their construction by Space Technology of Ireland they were tested in Budapest, Hungary, before being taken to the Baikonur Cosmodrome. The Irish have built other science equipment for the mission under similar agreements with Austria's Technical University in Graz.

Spacecraft Design

The Phobos spacecraft is of a new type designed by Soviet specialists to see service through the 1990's on various planetary flights.

It consists of a combined braking/correction propulsion system (CBPS) and toroidal and cylindrical equipment compartments, which contain the control subsystem, communications subsystem, chemical batteries of the power subsystem and science equipment electronics. Solar panels, a high gain antenna, attitude and stabilisation thrusters, attitude control star sensors, TV system and science payload are all mounted on the spacecraft exterior.

The high gain antenna is mounted

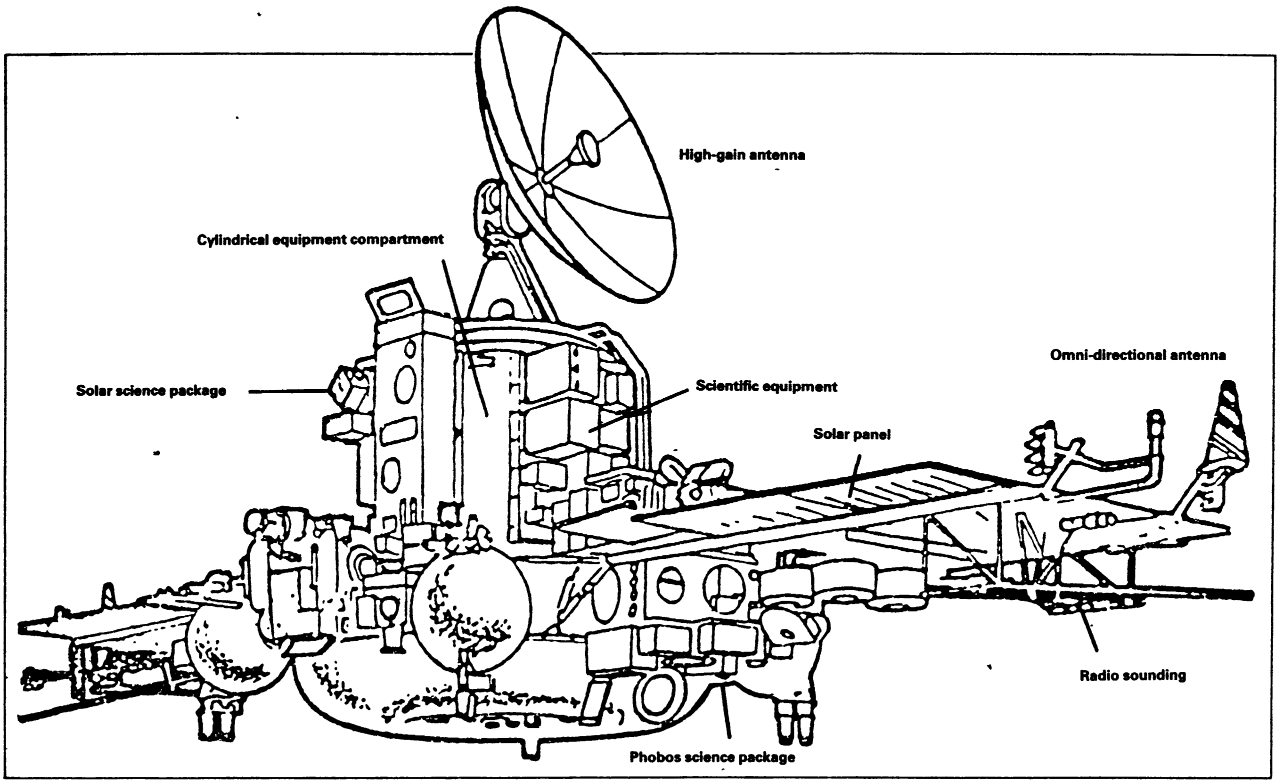


Diagram of the Phobos spacecraft

on the upper side of the cylindrical equipment compartment and is hinged to the body of the spacecraft with a two degree gear for pointing at Earth.

The altimeter antenna and radio sounding antennas are mounted under the solar panels. The attitude control jets and omni-directional antennas are installed at the ends of the panels, with the attitude control subsystem optics and electronics in the toroidal bay.

Propulsion System

The CBPS is a two-stage system. The first is called the Autonomous Propulsion System (APS) and is designed for correction manoeuvres during the Earth to Mars coast and for the 'three pulse' transfer into the observation orbit at Mars. Previous propulsion systems such as the CBPS-417 and CBPS-425A used on the Luna and Venera spacecraft were earlier versions of the same system.

The APS, discarded after the spacecraft is inserted into its observation orbit, is an integral tank cluster of eight spherical tanks made from aluminium alloy and linked together. The central unit comprises four tanks each 730 mm in diameter attached by two adapters. The outer four tanks, each 1020 mm in diameter, are attached to the central unit by distance adapters.

The central tank unit contains propellant for near-planet manoeuvres, the peripheral ones have some 3,000 kg of fuel for the mid-course corrections and orbital injection. APS design provides possibilities for separation of the peripheral tanks and in this way the spacecraft could be adapted for different planetary missions.

A multi-firing sustainer engine with pump feeding of self-igniting fuels (nitrate oxidiser and amines-based fuel) is mounted in the middle part of the central unit.

Soviet designers from the Babakin Bureau who designed the APS say that an integrated APS configuration with a low centre of mass caused problems with spacecraft stabilisation control in pitch and yaw during operation of the sustainer engine. The problem was solved by placing the combustion chamber in a special suspension which provides chamber movement in two perpendicular directions.

The APS is a pressure-fed system using helium to inflate an expandable device made of multilayer films of fuel-resistant fluoroplastic with a low diffusion permeability to feed the fuel and oxidiser from each tank.

The CBPS second stage consists of one central and four peripheral tanks, the latter carrying seven thermocatalytic propellant hydrazine thrusters.

There are 28 thrusters in total, with 24 of 50 N thrust and four of 10 N thrust. They are used for stabilisation and small correction manoeuvres during the transit as well as all the spacecraft manoeuvres after APS separation.

The CBPS second stage also has a system of gas jets for attitude control during the cruise phase. The fluid for the system is obtained by decomposition of hydrazine in the gas generator. The thrust of the engines is 0.5 N and the gas temperature does not exceed 80 degrees centigrade.

Thermal control of the CBPS is implemented by a combination of electric heaters and passive devices.

General Spacecraft Description

The subsystem provides all the modes for manoeuvring and attitude control. It includes a gyro-stabilised platform, a digital computer complex, an accelerometers module, automatics and pyrotechnics, solar and stellar sensors and the multiplexing unit.

The communications and data handling subsystem is able to store data and replay it to Earth at a maximum rate of 4 kbit/sec. The memory capacity of the system is 30×10^{16} bits. It provides reception, decoding of commands, distribution of commands between the spacecraft subsystems, radiometric data measurements and transmission of telemetry to Earth.

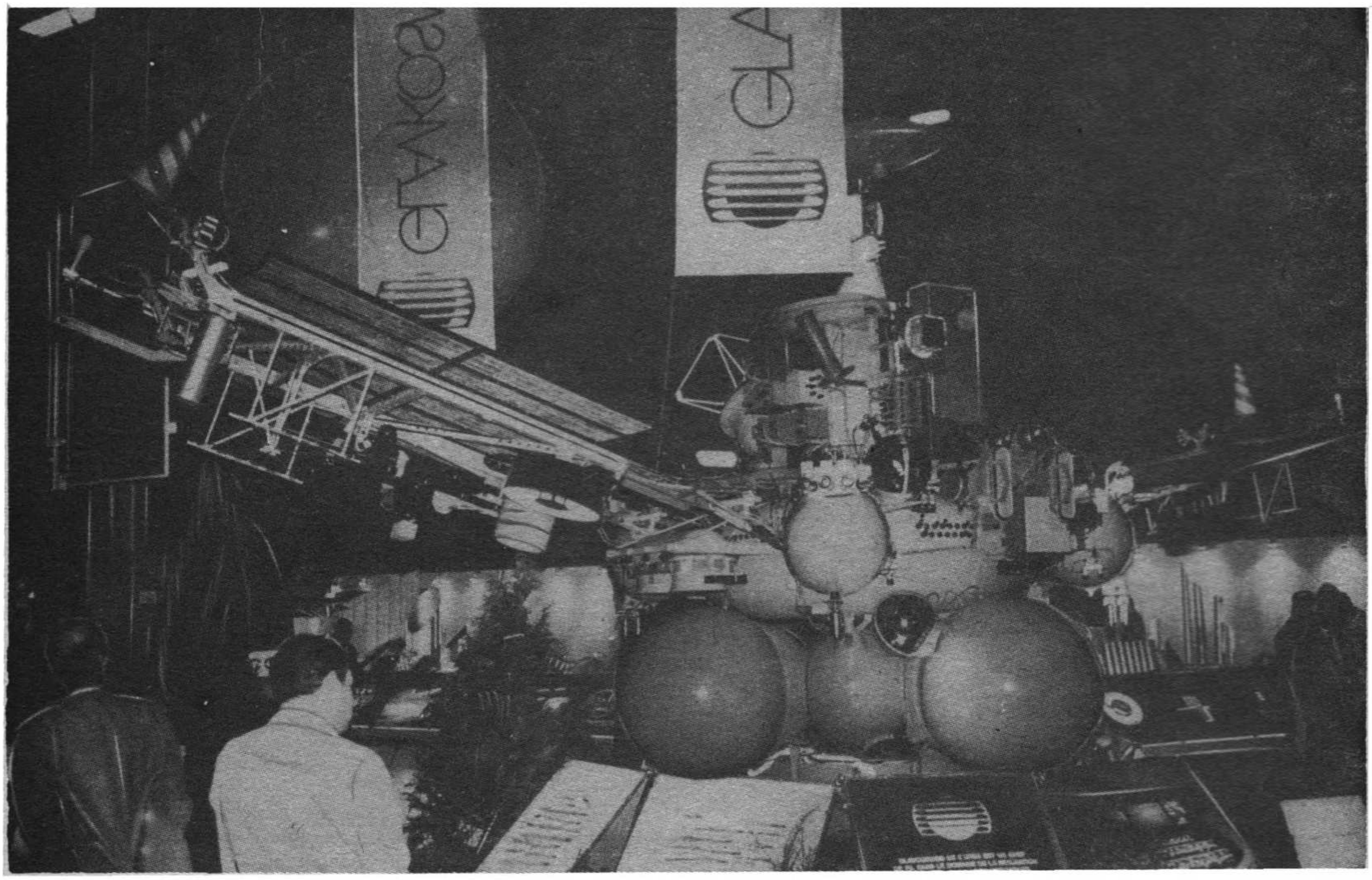
Electricity is generated by the two solar panels and the spacecraft also carry primary and secondary chemical batteries. The primary provides power during eclipse periods and when the spacecraft needs more power than can be obtained directly from the solar panels. The secondary battery provides power during the Phobos approach phase.

Thermal control is by both passive (thermal insulation) and active (gas circulation) means.

The complement of scientific equipment is mounted on the spacecraft exterior, with the Phobos science instruments on the toroidal compartment and the solar telescopes on the cylindrical compartment.

The descent vehicle is located on top of the spacecraft and a special manipulator will jettison the LAL (Long-term Automated Lander) and the Hopper descent craft from its platform.

In the initial phase of the Phobos mission definition the Soviets examined two options for the spacecraft; landing the spacecraft on Phobos



Full-scale replica of the Phobos spacecraft as displayed at last year's Paris Air Show

or hovering. The choice for the hover option came as a result of the absence of any significant gravitational pull. It also offered the opportunity to sample more areas of the moon than possible from a single site.

Future Design Options

The Soviets are examining future options for design of the Phobos-type spacecraft. They have described variants with different CBPS configurations for missions to Venus and the Moon. Other scientific equipment or "piggyback" vehicles could be mounted on the spacecraft for missions to asteroids or comets. For example, the Soviet/French Vesta mission is planned to carry a Soviet descent vehicle, a French asteroid vehicle and a Soviet probe/penetrator placed on the upper half-sphere of the spacecraft. The spacecraft could also be equipped with legs for landing on celestial bodies.

Phobos Flight Plan

The Earth to Mars cruise will last 200 days. Mid-course corrections with the APS are scheduled for either the 7th or 10th day after launch and the 7th or 15th day before Mars arrival. The exact timings will be determined after Earth-Mars transit injection.

At Mars arrival the APS will place the spacecraft into a highly elliptical orbit with a three day period (apogee = 79,000 km, perigee = 4,200 km). After 10 or 12 days in this orbit another firing will alter the orbit to one with a 3.3 day period (a = 79,000 km, p = 9,700 km) with the inclination matched to the plane of Mars' equator. The next manoeuvre will circularise the orbit to 9,700 km, some 350 km above the orbit of Phobos. The Soviets call this the "observation orbit", which will take almost 30 days to establish. The spacecraft will be in the observation orbit for another 30 days. With the APS discarded after attainment of the observation orbit, all subsequent manoeuvres will be made by the second stage of the CBPS.

During its time in the observation orbit the spacecraft will make autonomous navigation measurements of the relative movements of Phobos and itself. These will update the ephemerides of the moon to allow the beginning of the close approach phase. The observation orbit period will also see the most intensive period of Martian observation.

The transfer to Phobos synchronous orbit will be achieved by two manoeuvres and the spacecraft will stay in this orbit for 60 days. The final approach sequence will use doppler radar, radioaltimeter and altimeter data. There are some constraints on the geometery required at the so-called "hover phase" and these are the need to time the final approach sequence so that the Phobos-spacecraft line of sight is aligned with Earth and a solar phase angle of 0 - 135 degrees is maintained.

The close encounter period begins at an altitude of 2 km and lasts for about an hour. The spacecraft will be manoeuvred to a point just 50 metres above the surface of Phobos where it will seemingly "hover" for a 15 to 20 minute period moving at a speed of only 2 to 5 metres per second. At this point the laser and ion beam devices will be activated to conduct their investigations. At the end of the hover phase, the descent vehicle will be jettisonned to land on Phobos.

Another manoeuvre will place the spacecraft back in its orbit 2 km from the moon and from this distance the radar sounding experiment will be conducted.

A final manouvre will then place the spacecraft into an orbit with a perigree of 9,400 km.

Science Objectives and Equipment

The moons of Mars were first sighted by US Astronomer Asaph Hall in 1877 (there will be a plaque aboard each spacecraft to commemorate this) and the main objective of the Phobos flight is to understand more about one of the Solar System's small bodies.

Measurements by American Mariner and Viking spacecraft have shown both Phobos and Deimos to be an irregular chunk of rock. Phobos is 27 km along its longest axis and has a density of 2g/cm^3 which is consistant with a carbon chondrite, a recognised type of meteorite, and similar to materials found in type-C asteriods. There exists the possibility that both Phobos and Deimos are captured asteriods.

Scientists are naturally keen to

understand more precisely the material that forms Phobos and for this purpose the spacecraft carries a novel set of laser and ion beam devices to provide data on the isotope and mass composition of the moon's surface.

The LIMA-D experiment uses a laser beam with an energy of 0.5 joules operating at a wavelength of 1.06 microns. The laser beam is to be focussed for 10 nanoseconds on a 1-2 mm diameter spot on Phobos directly under the spacecraft. This will cause a blast-like evaporation and ionisation of the surface matter. Some of the scattered ions will be collected by devices on the spacecraft and will be analysed by a mass-spectrometer. During one cycle of measurements about 10^6 ions will be counted. Each cycle of measurements will last five to 10 seconds during the hover phase. The laser will vapourise the surface to a depth of about 2 microns.

Testing of the LIMA-D instrument was accomplished at the Moscow Space Research Institute. It was test-fired in a large vacuum chamber at a small fragment of meteorite. The instrument has a mass of 70 kg.

The DION experiment uses an ion beam to accelerate Krypton ions to 2-3 keV which will strike out secondary ions from the moon's surface to be registered on a mass-spectrometer. Other instruments will also register secondary ions formed by the natural ion current – the solar wind. The experiment has a mass of 18 kg.

Both the LIMA-D and DION experiments will operate over the moon during the hover phase of the mission allowing about 100 separate areas of the surface of Phobos to be measured and analysed.

TV images taken by the Fregat system during the approach and hover phases will have resolutions down to just 6 cm. The images and spectrograms of Phobos' surface will be used to compose a map of the surface of the moon to improve on those made from the US spacecraft. The TV lenses use rotational mirrors to aim at Phobos, Mars or the stars for navigational tasks. The system mass is 50 kg.

Infrared and gamma-ray spectroscopy will help understand the thermal and reflective properties of the surface and its minerological make-up. The gamma-rays will analyse basic ground elements such as iron, silicon, aluminium, calcium and magnesium as well as natural radioactive elements – uranium, thorium and potassium. The relative breakdown of these elements should provide a good source of information about the thermal history of Phobos.

The GRUNT experiment will use a radar complex located under the solar panels to probe the surface of Phobos to a depth of two metres. Data on the moon's inner structure and electrophysical characteristics will be provided by the 35 kg pulsed radio sounding equipment.

Following the immediate end of the hover phase two landers will be ejected from the spacecraft to drift to Phobos' surface. One is known as the Long-term Automated Lander (LAL) and, immediately after touchdown on Phobos, it will activate a "harpoon gun" device which will anchor the LAL to the surface by means of a penetrator and lanyard. The penetrator has been tested to a depth of 10 m in sandy ground and 0.5 m in sandstone. The requirement to anchor the LAL arises from Phobos' extremely weak gravitational field – just 1/1000th that of Earth's. The LAL needs a mechanical linkage to ensure correct orientation with its landing plate face down. Three solar panels will unfold after any disturbed dust has settled.

The module's main equipment platform will be elevated some 80 cm above the moon's surface and, after deployment of the solar panels, an optical transducer will keep them aimed at the Sun. The batteries of the LAL are expected to operate for two months after which the orientation procedure will be repeated in order to maintain power and ensure correct orientation of the Earth-aligned transmitting and receiving antennas.

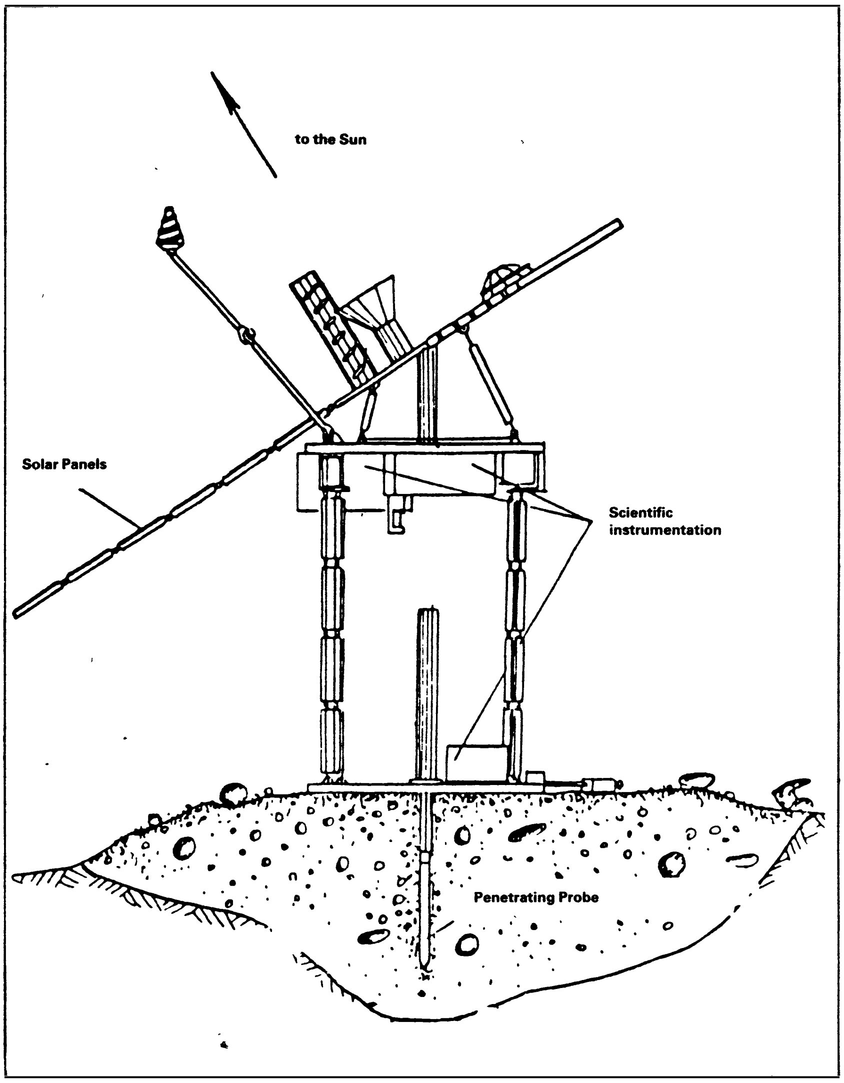
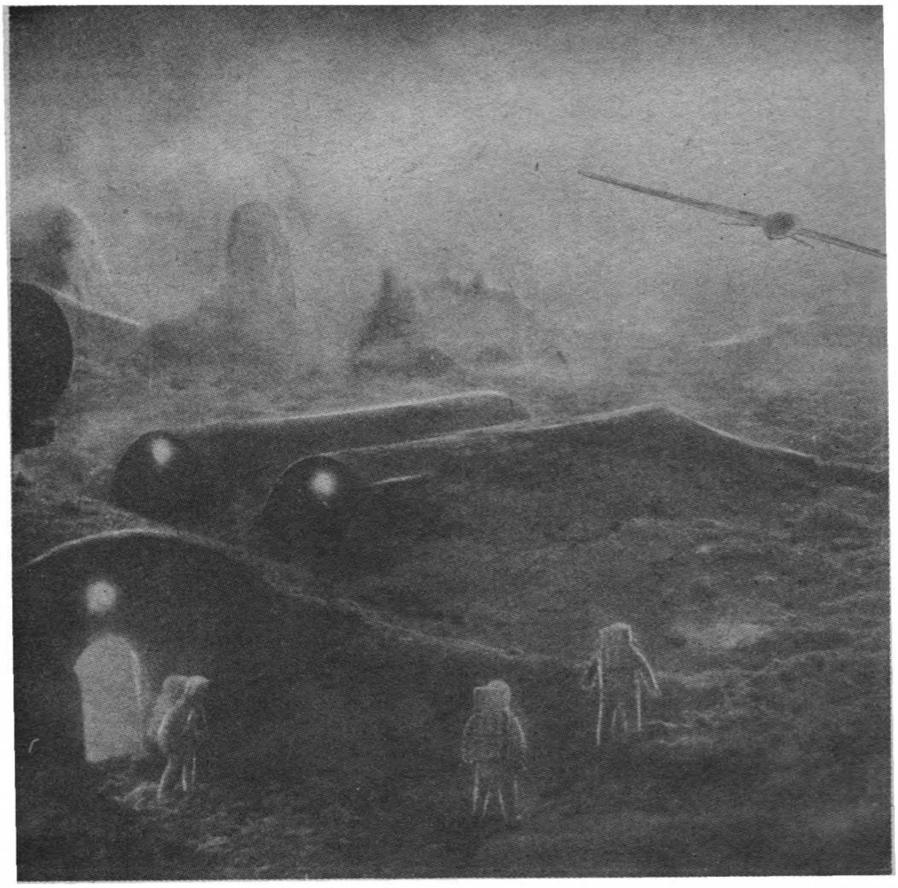


Diagram of the Long-term Automated Lander (LAL)

The antennas are located on the solar panels and once every Phobos day (7 hr 39 min 26.6 sec) LAL-Earth contact will be made and data will be returned concerning the condition of the LAL and its velocity and distance in relation to the Earth-borne monitoring stations. There is a microprocessor on the LAL to process the data before returning it to Earth.

The LAL science equipment consists of a spectrometer to determine the elemental composition of the surface of Phobos and a seismometer to probe the inner structure. It also has a TV system. Radio signals will be used to determine Phobos' position in the system of coordinates linked to Earth and related to quasars as part of an experiment to determine a more accurate value for the Astronomical Unit. The solar sensor will provide data about Phobos' libration and its mass distribution.

The second variant of the lander is called the Hopper which is designed to provide data on the chemical composition and physical characteristics of the Phobos surface. It carries an X-ray flourescence spectrometer, a mag-



An early manned base on Mars. *J. Baum*

netometer, a penetrometer, a dynamograph and a gravimeter.

Spherical in shape, it will be ejected from the spacecraft at the end of the hover phase and will deploy special "whiskers" after jettisoning its container. It will then be positioned by the "whiskers", conduct scientific measurements and then "hop" to another location on Phobos for another series of measurements.

The Soviets are studying the possibility of targetting the second spacecraft to perform similar operations at Deimos if the first spacecraft at Phobos is a complete success.

Whilst the Soviets state that Phobos is the main aim of the mission they also plan to conduct extensive observations of the planet Mars itself. The spacecraft carry instruments to explore the planet's surface, atmosphere and magnetosphere.

There are still many important unanswered questions about the planet, despite the success of the American Viking mission, relating to the amount of water vapour in the atmosphere, the temperature profile of the surface and the temperature cycle and thermal inertia of the ground.

Other investigations of the Martian atmosphere will seek to determine the distribution at various altitudes of carbon dioxide, ozone, molecular oxygen and other elements. Among the techniques to be used are spectral analysis of solar radiation as it passes through the Martian atmosphere.

The spacecraft will also carry a "plasma complex" of instruments to determine the extent of the Martian magnetic field, if it has one. Some scientists think the magnetic field may be so weak that it allows the solar wind to penetrate the upper rarefield layers of the atmosphere. The ionosphere will be observed by pulsed radio sounding.

Observations of the Sun will be conducted using a telescope mounted on the spacecraft. A major aim of the solar observations is to view the solar corona whilst the Earth and Mars are close to superior conjunction. When the observations are compared with Earth observations scientists hope to build up a three dimensional view of the solar corona.

The solar instruments on Phobos are an X-ray imaging telescope, X and gamma-ray spectrometers and a visible wavelength instrument to measure the intensity of solar radiation, possibly to confirm the existence of "solar pulses".

Future Programmes

The Soviets have described an ambitious programme of Mars exploration to the turn of the century in documents presented to the International Astronautical Federation (IAF).

In what the Soviets call the "first phase of Mars exploration" the future missions will involve both orbital and descent craft, the orbital section relaying data from the surface craft.

The descent portion would contain a lander, with a small Mars rover vehicle, balloons which would float from location to location during an extended period, and possibly a penetrator probe.

The Soviets are currently studying two methods of injecting vehicles into Martian orbits – powered braking and aerodynamic braking, involving use of a special nose shield.

First launch in the programme would be in September or October 1992 and the Soviets are currently describing the mission, called Columbus, as an orbital survey mission. The flight would be flown in tandem with the Mars Observer mission due for launch by the USA in the same window on STS-64.

The next Mars window, October 1994, may see the launch of the small rover vehicle and the balloon sondes, which are to use a French system in which a two-balloon configuration will allow the payload to be flown during Martian daytime and to land during the Martian night where it will sample the surface.

One of the rovers being proposed has a soil scooper with onboard analysis equipment and a total science payload of 150 kg. It would be powered by a small nuclear power-plant similar to those used for the US Pioneer and Voyager spacecraft and data would be routed back to Earth via the orbiter.

The return of Martian soil samples to Earth would be a logical follow-on target. The Soviets have outlined a number of options for this and it is possible that the mission may be a joint one with USA.

After landing on the surface of Mars, the current Soviet proposal describes a rover vehicle leaving the vicinity of the descent craft and travelling a large distance from that location, sampling the soil and conducting preliminary analysis.

After returning to the vicinity of the descent craft the samples would be offloaded automatically into a return vehicle which then blasts off into either Mars orbit or an Earth-return trajectory. In the latter case the return vehicle would be located on the rover.

The return vehicle could then either land on Earth or be injected into an Earth orbit where it would be intercepted by a manned crew and the samples analysed on the Soviet orbital station which will replace Mir. This latter method, the Soviets say, would allow the Earth's biosphere to be protected from contamination with any possible microorganisms which may be brought from Mars.

There are no explicit plans from the Soviets beyond this stage for a Mars landing by humans or any detailed investigations into the possibility that Mars has indigenous life forms.

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Roald Sagdeyev

Director of the Institute of Space Research of the USSR Academy of Sciences, *Roald Sagdeyev*, talks about Mars exploration.

In the early sixties many predicted that a spaceship carrying three or four people would be sent to Mars in the 1980's. Why has such a project not been realised?

Sagdeyev: There are many reasons. Considerations of both a financial and a technical nature play no small part. After the Apollo programme there was much talk in the USSR about the next manned mission – this time towards Mars. But one should not forget that circumterrestrial and even lunar flights are one thing, and a Martian mission is something totally different.

The Soviet Union has sent seven automatic probes weighing a total of almost 26 tons towards Mars. The combined weight of manned space modules now operating in circumterrestrial orbits, making up, say, the Mir complex, is measured in dozens of tons.

For a Martian manned flight it would be necessary to lift at least several hundred tons of payload into space. This means that either super launch vehicles would have to be developed or an interplanetary spacecraft would have to be assembled in orbit from a multitude of separate units. Both variants at present pose a challenging task.

A flight to Mars would take two or three years. Could human beings endure such a long expedition? Until recently the 237 day flight aboard the Salyut 7 complex performed by Soviet astronauts Leonid Kizim, Vladimir Solovyov and Oleg Atkov in 1984 was an all-time record. In 1987 Yuri Romanenko beat this record on board the Mir complex. The periods are impressive but insufficient.

A Martian mission would also require great expediture which would only be justified in the event of automatic devices exhausting their capabilities.

How will the exploration of Phobos be organised technically?

Sagdeyev: It will take a fairly long period of time to adjust the probes' orbits to that of Mars' natural satellite. It is assumed that the probes will fly over Phobos at an altitude of several score metres only, and the difference in their speed will be close to the pace of a marathon runner. The entire fly-by over Phobos will take about 20 minutes, but a great amount of work will have to be performed during that time.

For the first time in the history of the exploration of other planets, the rock composition of a celestial body will be studied with the aid of a laser beam. A pencil-beam sting aimed at the surface will cause a micro-explosion and the evaporation and ionization of surface rock. Part of the ions will hit the probe's instruments and be recorded by them.

Besides these measurements, the satellite's surface will be televised and colour photographs will make it possible to discern terrain features only several centimetres in size.

And what will follow the Phobos project? Could it be that in the early 1990's vehicles like Mars rovers or recoverable rockets fetching Martian rock to Earth will be developed?

Sagdeyev: We recognise the need for a long-term programme which will clearly define the goals of Martian research for, lets say, the remaining years of our century. One anticipates the delivery of Martian rock samples to Earth as one such goal, perhaps, the most extensive of them all.

Only in ground-based laboratories using unique and highly sensitive instruments and methods would it be possible to make an exhaustive analysis of Martian matter. Such characteristics of Martian rock samples as the presence of rare isotopes will give us an idea of the processes and natural cataclysms which attended the emergence of the solar system. Besides, it is very likely that such detailed analysis of rock samples will permit us to determine once and for all whether life, albeit in the most primitive form of the simplest micro-organisms, ever existed on Mars.

The delivery of rock samples from the planet is a task, perhaps, for the late 1990's, but until then a series of two or three intermediate flights could be contemplated to prepare for the landing of an unmanned expedition on Mars. Such "Intermediate" vehicles could include artificial Martian satellites, Mars rovers and special balloons.

Essentially, Mars rovers could explore relatively large portions of the Martian surface and select and automatically analyse rock samples in the most interesting places. Balloons could perform flights at low altitudes in the exceedingly rarefied Martian atmosphere. Consequently, a recoverable rocket has more chance of selecting the most promising region of the planet for taking rock samples.

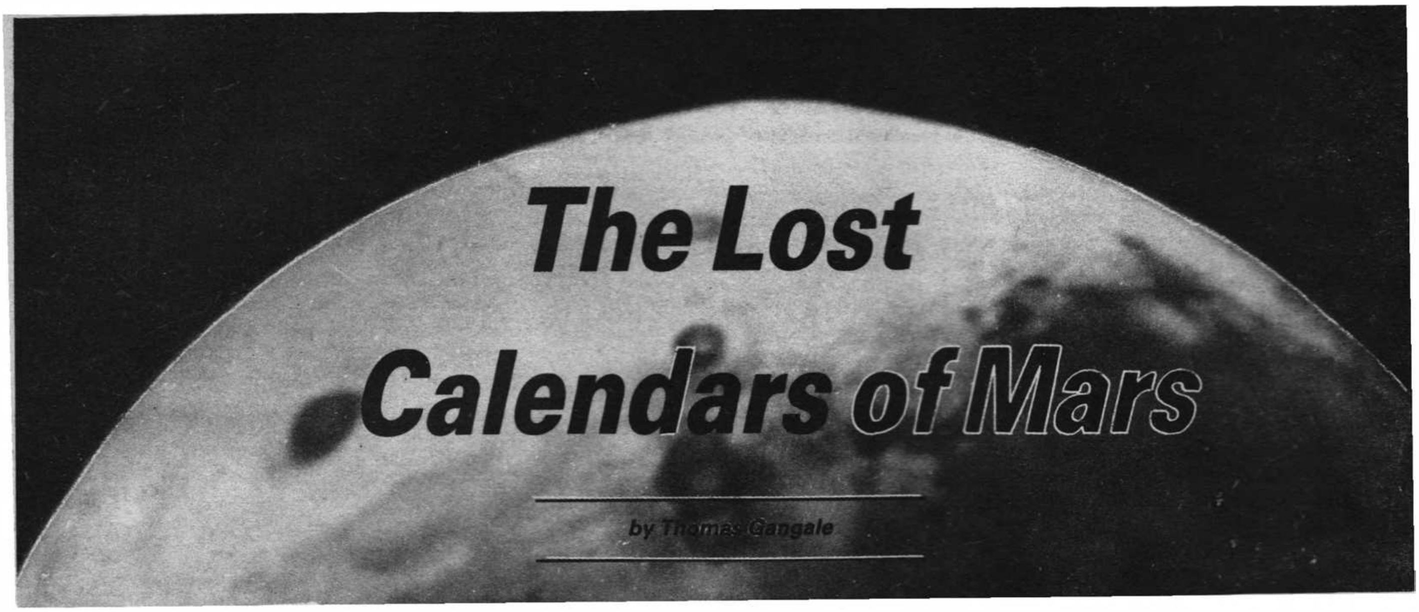
Preparatory work involving intermediate vehicles is already in progress. The first trials of a special balloon designed for a Martian launching have been conducted on Earth. This development is a joint project implemented in cooperation with French and American scientists.

The concept of a Mars rover has also been developed in greater detail. This kind of apparatus should possess certain elements of artificial intellect. The point is that the transmission of radio signals from Mars to Earth and vice versa takes several mintues, so it would be very difficult to control the movements of the Mars rover over the planet's surface: a hillock, a large boulder, a hollow – the craft could, in fact, encounter any obstacle. The artificial intellect, which will control the movement, should be programmed to cope with such situations and take independent decisions when selecting its route during the Martian excursion. Plainly, it should also be equipped with its own sense organs.

A wide range of Martian projects that could be implemented, given the integration of Soviet and US efforts, were discussed at recent meetings of Soviet and American experts, were they not?

Sagdeyev: Indeed, many ideas were put forward. For example, towards the close of this century the two countries could send to Mars automatic probes which would return to Earth Martian rock samples. An exchange of such rock samples would be very useful to the scientists of the two countries and for world science as a whole. Some American scientists, including Carl Sagan and others, advance even bolder ideas, such as a joint manned flight to Mars. One may doubt the expediency of this project or argue for or against it, but Carl Sagan is unquestionably right in saying that a joint mission would cost less than other less desirable areas of research.

The above is an abridged version of an interview with Roald Sagdeyev published by Novosti



> *What profit hath a man of all his labour which he taketh under the Sun?*
>
> *One generation passeth away, and another generation cometh: but the Earth abideth forever.*
>
> *The Sun also riseth, and the Sun goeth down, and hasteth to his place where he arose.*
>
> *The wind goeth toward the south, and turneth about unto the north; it whirleth about continually, and the wind returneth again according to his circuits.*
>
> *All the rivers run into the sea; yet the sea is not full; unto the place from whence the rivers come, thither they return again.*
>
> *All things are full of labour; man cannot utter it: the eye is not satisfied with seeing, nor the ear filled with hearing.*
>
> *The thing that hath been, it is that which shall be; and the which is done is that which shall be done: and there is no new thing under the Sun.*
>
> *Is there any thing whereof it may be said, See, this is new? It hath been already of old time, which was before us.*
>
> Ecclesiastes

The Lovelock-Allaby Calendar

I happened to come across *The Greening of Mars* at about the time that I was submitting my original article to the British Interplanetary Society. In their 1984 book, James Lovelock and Michael Allaby concluded as I did that Martian time must be based on the Solar cycles of Mars, both the diurnal and the annual. Their Martian clock, like mine, was basically a 24 hour Terran clock reduced in speed by 2.74913 per cent to coincide with the length of the Martian mean Solar day. I disagree with them in that I believe they were unduly pessimistic concerning the ability of human biological circadian rhythms to adapt to this very slightly longer day. Also, I cannot foresee that there would ever be justification to use Martian clocks anywhere off Mars except as necessary to reference events on Mars itself.

Although they noted the correct length of the Martian Solar day as 24 hours 39 minutes 35 seconds and intended that their Martian calendar be based on the Martian Solar year, they made the mistake of having 687 days in their calendar when this is in fact the number of Terran Solar days in a Martian Solar year. It was as obvious to Lovelock and Allaby as it was to me that the cycles of Phobos and Deimos are entirely unsuitable as the bases for units of time. But, whereas I chose to adopt an artificial chronometric unit based on the cycle of the Moon, there are no months at all in the Lovelock-Allaby calendar:

> *We do not count months. On Earth these are based, clumsily, on the orbit of the Moon. Indeed, we have two tiny moons that look about the size Venus looks when seen from Earth. A division of the year into months would force us to choose one in preference to the other, and that would cause endless wrangling among the Phobos and Deimos factions that would spring up instantly. Even then it would not be easy. Phobos orbits Mars three times each day, and Deimos takes rather more than a day to make a single orbit. Martian months would be rather different from Terran months! Perhaps we could use both and try to devise a double-month system. I cannot begin to imagine what that would be like.*

Recognising the sociological necessity of the seven day week, Lovelock and Allaby adopted this unit of time which has no astronomical analogue either on Earth or Mars. Their calendar thus consists of days, weeks, and years. They retained the same names of the days of the week that are used on Earth, and the weeks themselves were numbered from the beginning to the end of the year. As their fictional character explains:

> *My date of birth, for the record, was 3.68.06. That is to say, I was born on the third day (which we call Tuesday, as I said) of the sixty-eighth week of the sixth year of the century. We omit the number of the century, but I was born in the year 106.*

Although Lovelock and Allaby were not explicit on this point, the above passage implies that they intended each year and each week to begin on Sunday. If we assume a year of 687 days as Lovelock and Allaby did, we find that seven divides this number 98 times with a remainder of one day. This last day of the year would in effect be an intercalary day, for in their system the dates of the last two days of the year and the first day of the following year would be 7.98 (a Saturday), 1.99 (a Sunday), and 1.01 (another Sunday). But if we correct their error and consider years consisting of 668 and 669 days, we find that the 96th and final week would be only three or four days long, and of course Lovelock and Allaby did not confront the social desynchronisation that might result from this. The Egyptians, for instance, who had five intercalary days at the end of their Solar calendar, did not try to resolve this anomalous period into something resembling a regular work week, but rather dealt with it by instituting a festival of five days in celebration of the rising of Sirius above the morning horizon and the rising level of the Nile. The Darian calendar avoids this issue by having a six-day week at regular intervals throughout the year. It is not so much that I am against having a big blow-out at the end of the year; I just prefer to have as symmetric a calendar as possible.

Lovelock and Allaby chose to begin their Martian chronology with the establishment of the first human outpost on Mars. They were unclear as to whether they intended the anniversary of this event to be New Year's Day on their calendar. In any case, since the beginning of their chronology is defined by an event which has yet to come about, their calendar cannot be referenced to the Gregorian calendar.

The Aitken Calendar

Before either man or machine ventured into space, before the first transistor and the first digital computer, the astronomer Robert G. Aitken envisioned a human civilisation on Mars and foresaw the need for a calendar based on the diurnal and annual cycles of that world. Aitken beat Lovelock, Allaby, and me to the punch by over three decades, but by the 1980's, when the subject of human expeditions to Mars and the colonisation of that world at last began to be given wide and serious consideration, his Martian calendar had been forgotten. The Aitken calendar is truly a lost calendar of Mars. It would have been easy to leave it buried, and certainly safer for the Darian calendar not to call attention to a potential rival, but regardless of whatever calendar the Martians eventually choose to adopt, the Aitken calendar is part of their heritage, and it would have been less than honest of me to conceal what I unearthed. Of course, only time will tell if my own work is in turn forgotten.

his odd-numbered years 668 days long and his even-numbered years 669 days long, and therefore every tenth year had 670 days. In contrast, all odd-numbered years have 669 (an odd number) days in the Darian calendar, and except for those years divisible by ten but not 1,000, which also have 669 days, all even-numbered years have 668 (an even number) days. Thus the Aitken calendar had years of three different lengths, while in the Darian calendar years come in only two varieties. Lacking the 1,000-year correction factor, the Aitken calendar is still accurate to a day over that period of time.

Aitken also dispensed with months as Lovelock and Allaby did, and like them he retained both the seven day week and the Terrestrial names of the days of the week. But while the Lovelock-Allaby calendar divided the year into units no larger than the week,

Table 1. The Aitken Calendar's two year cycle.

	Spring		Summer		Autumn		Winter	
Odd-Numbered Years								
Qtrs.	First Day	No. of Days	First Day	No. of Days	First Day	No. of Days	First Day	No. of Days
1	Sun.	42	Sat.	42	Fri.	42	Thu.	42
2	Sun.	42	Sat.	42	Fri.	42	Thu.	42
3	Sun.	42	Sat.	42	Fri.	42	Thu.	42
4	Sun.	41	Sat.	41	Fri.	41	Thu.	41
Even-Numbered Years								
Qtrs.	First Day	No. of Days	First Day	No. of Days	First Day	No. of Days	First Day	No. of Days
1	Wed.	42	Tue.	42	Mon.	42	Sun.	42
2	Wed.	42	Tue.	42	Mon.	42	Sun.	42
3	Wed.	42	Tue.	42	Mon.	42	Sun.	42
4	Wed.	41	Tue.	41-42	Mon.	41	Sun.	42

It was in a 38-year-old book about Mars that I chanced across a passing reference to a Martian calendar, which attributed the invention to the astronomer Robert S. Richardson. Eventually, I tracked down Richardson's 1954 book *Exploring Mars*, only to find that he named Aitken as the inventor of the calendar. He did give his opinion on the Martian clock, however, recommending that it be simply a slowed-down version of the 24 hour Terran clock.

Richardson led up to his discussion of the Aitken calendar by entertaining various methods of dealing with the fractional portion of the 668.599 day year. The first scheme had common years of 669 days and every fifth year consisted of 667 days. In the second method, common years would be 668 days and every fifth year would contain 671 days. Aitken's solution was to have the years run alternately 668 and 669 days and insert an extra day in every year whose number was divisible by ten. This is strikingly similar to the Darian calendar, except that Aitken had

Aitken devised two intermediate periods of time. He first divided the year into equal quarters of approximately 167 days, which he called "seasons" and named Spring, Summer, Autumn and Winter. Each "season" he quartered in turn so that each sixteenth of a year contained about 42 days, or six weeks. These sub-divisions of the "seasons" Aitken called "quarters", although this term usually connotes a quarter of a year.

Indeed, while he chose not to call them months, in order to keep the terminology in this article consistent, one can think of them as such. Now, owing to the fact that the naturally-occurring seasons of Mars are quite asymmetric, there would be a very poor correlation between these and Aitken's symmetric "seasons". Assuming that Aitken's calendar began with the vernal equinox, he would have his first day of Summer 27 days before the summer solstice, his first day of Autumn 37 days before the autumnal equinox, and his first day of Winter 12 days before the winter solstice.

Table 2. Conversion of Darian calendar dates to numerical values.

Day	Month Sag	Dha	Cap	Mak	Aqu	Kum	Pis	Min	Ari	Mes	Tau	Vri
1	1	29	57	85	113	141	168	196	224	252	280	303
2	2	30	58	86	114	142	169	197	225	253	281	309
3	3	31	59	87	115	143	170	198	226	254	282	310
4	4	32	60	88	116	144	171	199	227	255	283	311
5	5	33	61	89	117	145	172	200	228	256	284	312
6	6	34	62	90	118	146	173	201	229	257	285	313
7	7	35	63	91	119	147	174	202	230	258	286	314
8	8	36	64	92	120	148	175	203	231	259	287	315
9	9	37	65	93	121	149	176	204	232	260	288	316
10	10	38	66	94	122	150	177	205	233	261	289	317
11	11	39	67	95	123	151	178	206	234	262	290	318
12	12	40	68	96	124	152	179	207	235	263	291	319
13	13	41	69	97	125	153	180	208	236	264	292	320
14	14	42	70	98	126	154	181	209	237	265	293	321
15	15	43	71	99	127	155	182	210	238	266	294	322
16	16	44	72	100	128	156	183	211	239	267	295	323
17	17	45	73	101	129	157	184	212	240	268	296	324
18	18	46	74	102	130	158	185	213	241	269	297	325
19	19	47	75	103	131	159	186	214	242	270	298	326
20	20	48	76	104	132	160	187	215	243	271	299	327
21	21	49	77	105	133	161	188	216	244	272	300	328
22	22	50	78	106	134	162	189	217	245	273	301	329
23	23	51	79	107	135	163	190	218	246	274	302	330
24	24	52	80	108	136	164	191	219	247	275	303	331
25	25	53	81	109	137	165	192	220	248	276	304	332
26	26	54	82	110	138	166	193	221	249	277	305	333
27	27	55	83	111	139	167	194	222	250	278	306	334
28	28	56	84	112	140		195	223	251	279	307	

Day	Month Gem	Mit	Can	Kar	Leo	Asl	Vir	Kan	Lib	Tul	Sco	Ali
1	335	363	391	419	447	475	502	530	558	586	614	642
2	336	364	392	420	448	476	503	531	559	587	615	643
3	337	365	393	421	449	477	504	532	560	588	616	644
4	338	366	394	422	450	478	505	533	561	589	617	645
5	339	367	395	423	451	479	506	534	562	590	618	646
6	340	368	396	424	452	480	507	535	563	591	619	647
7	341	369	397	425	453	481	508	536	564	592	620	648
8	342	370	398	426	454	482	509	537	565	593	621	649
9	343	371	399	427	455	483	510	538	566	594	622	650
10	344	372	400	428	456	484	511	539	567	595	623	651
11	345	373	401	429	457	485	512	540	568	596	624	652
12	346	374	402	430	458	486	513	541	569	597	625	653
13	347	375	403	431	459	487	514	542	570	598	626	654
14	348	376	404	432	460	488	515	543	571	599	627	655
15	349	377	405	433	461	489	516	544	572	600	628	656
16	350	378	406	434	462	490	517	545	573	601	629	657
17	351	379	407	435	463	491	518	546	574	602	630	658
18	352	380	408	436	464	492	519	547	575	603	631	659
19	353	381	409	437	465	493	520	548	576	604	632	660
20	354	382	410	438	466	494	521	549	577	605	633	661
21	355	383	411	439	467	495	522	550	578	606	634	662
22	356	384	412	440	468	496	523	551	579	607	635	663
23	357	385	413	441	469	497	524	552	580	608	636	664
24	358	386	414	442	470	498	525	553	581	609	637	665
25	359	387	415	443	471	499	526	554	582	610	638	666
26	360	388	416	444	472	500	527	555	583	611	639	667
27	361	389	417	445	473	501	528	556	584	612	640	668
28	362	390	418	446	474		529	557	585	613	641	669

Rather than having a six day week at the end of each quarter as needed and thereby enabling each quarter to invariably begin on the first day of the week as in the Darian calendar, Aitken allowed the days of the week to regress through his calendar over a two year period. His odd-numbered years began on Sunday, and since each "season" was 167 days – one day short of being evenly divisible by seven – his Summer began on Saturday, Autumn on Friday, and Winter on Thursday. In even numbered years, Spring began on Wednesday, Summer on Tuesday, Autumn on Monday, and Winter on Sunday. Since even numbered years contained 669 days, this last "season" was a day longer than normal; 168 being divisible by seven, the following Spring also began on Sunday to begin the two year cycle again. A nice feature of the Aitken calendar was that within each of the "seasons", all of the six week periods began on the same day of the week. Aitken treated the extra day that he inserted every tenth year as an intercalary day – having no day of the week – so as not to upset his biennial cycle. The leap day occurred at the end of Summer – halfway through the year – so Aitken called it Mid-Year Day and declared it a Holiday.

Aitken did not specify a starting year for his calendar, and so like the Lovelock-Allaby calendar, his cannot be correlated with the Gregorian calendar.

The Levitt Calendar and The Levitt-Mentzer Clock

While searching for the details of what at the time I believed to be Richardson's calendar, I discovered evidence of yet another lost Martian calendar – and the first construction of a Martian clock – invented by his contemporary I. M. Levitt. I also subsequently found that in addition to describing the Aitken calendar, Richardson mentioned the Martian calendar devised by Levitt in a footnote of *Exploring Mars*. Again, as with the Aitken calendar, Levitt's inventions were far enough ahead of their time that they eventually faded into obscurity; yet they deserve their place in Martian history, and a treatise on Martian time would be incomplete without a discussion of his work.

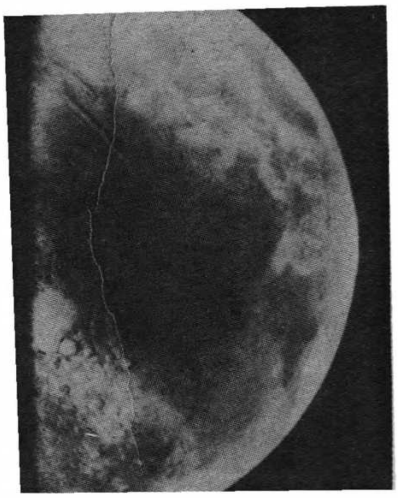
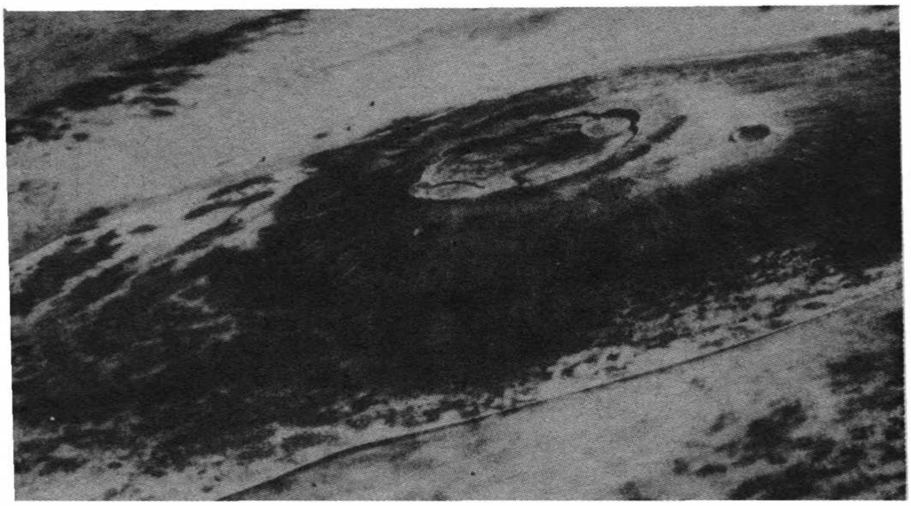
Levitt published his idea of a Martian calendar in the May 1954 issue of *Sky & Telescope*. He devised yet a different method of intercalation from those discussed by Richardson, the one adopted by Aitken, and that which is employed in the Darian calendar. He specified a five year sequence in which the first and fourth years were 668 days long and the other three years contained 669 days. Additionally, however, Levitt allowed for the omission of a leap day every 1,000 years, as does the Darian calendar, and therefore claimed for his calendar an accuracy of a day in 20,000 years.

Since the cycles of Phobos and Deimos are quite useless in connection with a calendar, and the Lunar cycle has nothing at all to do with Mars, it was quite reasonable for Aitken, Lovelock and Allaby to do away with months on their Martian calendars. From a social scientist's point of view, however, would it not be important to retain a chronometric concept that has been a part of most human cultures for centuries and even millenia?

I believe that a major advantage of the Darian calendar over these two competitors is that it demonstrates that months need not be abandoned on Mars, and that in fact months fit very neatly into the 668.5990 day Martian year. Levitt also saw that the month was a desirable unit of time to transplant to Mars; however, whereas I based my Martian months on the original model – the period of the Moon's orbit around the Earth – and arrived at a total of 24 months of approximately 28 days each, Levitt proceeded along a different line of reasoning and instead divided the Mar-

Simulated view of the Viking landing (above) on Mars in 1976 and (below) the first colour picture returned from the surface of Mars.

2412

Mars from the approaching Viking probe (left) and a close-up from orbit of the Oympus Mons volcano.

tian year into 12 months as do most calendars on Earth. Levitt's months are thus half as many and twice as long as mine, averaging just slightly less than 56 days each.

Of the four Martian Solar calendars discussed so far – the Aitken, the Levitt, the Lovelock-Allaby, and the Darian – Levitt's is the most conservative. He retained the same names of the 12 months of the year that date back to ancient Rome. Like the other three Martian calendars, the Levitt calendar inherited the seven day week from the Gregorian calendar, and like the Aitken and Lovelock-Allaby calendars, he preserved the Anglicised names of the seven days of the week. In my view, the similarity in nomenclature of any Martian calendar to the Gregorian calendar is an invitation to great confusion, and I have purposely avoided this in the Darian calendar. I have exported to Mars the concepts embodied in the Gregorian calendar where possible, improved upon them where I saw the opportunity, but I have changed the names of the months and the days to give the Darian calendar a distinctive Martian flavour and eliminate any possible ambiguity.

For all that, the architecture of the Levitt calendar is nearly identical to that of the Darian calendar. His calendar like mine and Aitken's, devides the year into equal quarters of 167 days, except in the case of the last quarter of a 669 day year, which is 168 days. But as opposed to Aitken, who employed unvarying seven day weeks throughout his calendar so that the days of the week slid backward from quarter to quarter, Levitt contrived a six day week to end each 167 day quarter. Thus, just as in the Darian calendar a six day week ends with Dies Veneris and is followed by Dies Solis, Levitt's six day weeks end with Friday and is immediately followed by Sunday. As a result, every month on the Levitt calendar begins with a Sunday, just as on the Darian calendar each month begins on Dies Solis. In fact, ignoring the differences in the names of the months of the year and the days of the week, if one were to bisect each month of the Levitt calendar, the resulting structure would be indistinguishable from the Darian calendar.

Table 3. Comparison of Martian Solar Calendars.

Calendar	Aitken	Levitt	Moore	Lovelock-Allaby	Darian
Year Published	1954	1954	1977	1984	1986
Number of Months	16	12	18	0	24
Days per Month	41-42	55-56	37-38	---	27-28
Weeks per Month	5.96875	8	---	---	4
Weeks per Year	95.5	96	---	96	96
Numerical Day of Vernal Equinox	1	545	---	---	1
Roman Calendar Reference	---	1 Jan 4713 BC	---	---	26 Dec 1975 AD
Intercalation Sequence	668 669 668 669 668 669 668 669 668 670	668 669 669 668 669 668 669 669 668 669	---	---	669 668 669 668 669 668 669 668 669 669
Accuracy	1,000 years	20,000 years	---	---	20,000 years

I chose to begin the Darian calendar with an historic Martian event and a Martian astronomical event: the vernal equinox prior to the landing of *Viking 1* on Mars. Lovelock and Allaby based their Matrian chronology on a Martian event which has yet to occur, and Aitken did not designate a beginning year for his calendar. Levitt, on the other hand, tied his Martian calendar to the beginning of the Julian Period – a Terrestrial event – since no historical event had at that time taken place on Mars.

So while the Aitken and the Lovelock-Allaby calendars cannot be referenced to the Gregorian calendar, the Levitt calendar, like the Darian calendar, can be. Also like the Darian calendar, Levitt began his with the year 0 rather than 1. Thus January 1 4713 BC on the Julian calendar was also January 1 0 MY (Martian Year) on the Levitt calendar. Although Levitt did not furnish an exact correlation between his calendar and a modern date on the Gregorian calendar in his 1954 *Sky & Telescope* article, he did state that January 1 1954 AD occurred in the year 3641 MY.

One of the most important aspects of a calendar is its relationship to the seasons, yet Levitt failed to mention whether his New Year's Day is in the Martian Spring, Summer, Autumn or Winter. It is possible to calculate the dates on which the equinoxes and solstices fall on the Levitt calendar and thus make it a bit more complete. Also, by so doing, we can establish a correlation between the Levitt calendar and the Darian calendar. 1 Sagittarius 0 ME on the Darian calendar corresponds to

JD 2,442,771.657. Dividing this number by 1.0274913 yields 2,377,413.4, the number of Martian Solar days that have elapsed since Jaunary 1, 0 MY on the Levitt calendar. If we divide further by 668.599, the integer portion of the quotient – 3555 –is the corresponding year on the Levitt calendar, and the remainder plus one – 545 – is the numerical day of the year. Since the structure of the Levitt calendar is so similar to that of the Darian calendar, Table 2 can be used to convert this numerical value to the corresponding Levitt calendar date if for the Sanskrit months we add 28; and for Sagittarius and Dhanasu we read instead January, February for Capricornus and Makara, et cetera. Thus Day 545 on the Levitt calendar, the date of the vernal equinox in the northern hemisphere, is 44 October, and so December 26, 1975 AD, 1 Sagittarius 0 ME, and 44 October 3555 MY are all equivalent dates. Further calculations of this nature show that January 1 on the Levitt calendar occurs in the late spring, with the summer solstice taking place on February 14. Similarly, May 24 marks the autumnal equinox and July 27 is the date of the winter solstice.

Now there is a serious discrepancy between the correlation of Levitt and Gregorian dates that Levitt himself reported and the result that I have reached here. How could January 1, 1954 AD be in the year 3641 MY if December 26, 1975 AD corresponds to 44 October 3555 MY? Levitt obtained his result by taking the Julian Day of January 1, 1954 AD and dividing this figure by the number of Martian Soalr Days in a Martian Solar year. Levitt's error was in not also dividing by the ratio of Terran Solar days to Martian Solar days, or alternatively he could have divided the Julian Day by the number of Terran Solar days in Martian Solar year to obtain the correct Martian Year of his calendar. It turns out that January 1, 1954 AD on the Gregorian calendar actually corresponded to 39 December 3544 MY on the Levitt calendar.

Hopefully, this error appeared only in Levitt's *Sky & Telescope* article and was not incorporated into the design of the Earth-Mars clock. Designed by Levitt and constructed in the home workshop of Ralph B. Mentzer of the Hamilton Watch Company, the clock was unveiled at the Waldorf-Astoria Hotel in New York on February 14, 1954. The main dial of the clock displayed 24 hour time on Mars; whether or not this was intended to be Martian Prime Meridian Time is unclear. Additionally, the clock had three smaller dials on its face: the first marked the day, month and year on Mars according to the Levitt calendar; the second displayed 24 hour GMT; the third showed the day, month and year according to the Gregorian calendar. The Levitt-Mentzer clock was capable of being run forward or backward at 2,000 times normal speed and stopped at any date between January 1, 1970 and December 31, 1989, and thus functioned as a mechanical analog computer for relating time on both worlds. Recall that at the time Levitt and Mentzer devised their clock, electronic digital computers were in their infancy.

And it was not only electronic computers that were in their infancy in 1954 when Richardson discussed Aitken's calendar in *Exploring Mars* and Levitt published his own calendar in the May issue of *Sky & Telescope*. I have always been one of those who dreamt of going to Mars and, strangely enough, I have always been very interested in calendars as well. Perhaps there was something in the air at the time of my birth. You see, on the Darian calendar I was born on 4 Vrisha -12 ME, which on the Levit calendar would be 30 February 3545 MY; but of course most Terrans are more familiar with their own Gregorian calendar, according to which my date of birth is May 13, 1954 AD.

The Moore Calendar

Having now found three Martian Solar calendars, I resolved to make a general search; how many more were out there, I wondered?

The Viking landings on Mars inspired an invasion of the bookstands by a host of books about Mars. One of them was Patrick Moore's 1977 *Guide To Mars*, and in it was still another Martian calendar. Moore's idea was to divide the Martian year into 18 months, all but three of which would be 37 days long. The 6th, 12th and 18th months were instead 38 days long. Moore made no mention of weeks in his calendar, and indeed, since 37 is a prime number, there is no hope of having an integral number of weeks – seven day weeks or otherwise – in his months. Yet the sociological need for this unit of time is incontraverti ble, and certainly the Martians will not do without it. Also, Moore did not take on the problem of intercalation to account for the fractional number of days in the year.

* * *

Although I had read many books and magazine articles about Mars before I began my work on Martian time, I was somehow unlucky enough never to have come across even one of these other Martian calendars. Or perhaps this was good fortune, for had I known in advance of a Martian chronometric system that pre-dated mine, I might have been daunted from plunging into the task with such zest as I have done in my happy ignorance. What I had assumed was a brand new field I have since come to see is already a rather crowded one, and there may be still other Martian calendars out there somewhere. But of all the ones that I have found, none can claim all of the features that are incorporated into my own Darian calendar:

a) A seven day week.
b) An integral number of weeks per month, enabling each month to begin on the first day of the week.
c) A 28 day month which approximates the familiar Lunar cycle.
d) A year which begins on the vernal equinox, symbolic of the beginning of life.
e) The simplest possible intercalation sequence, requiring calendar years of only two different lengths.
f) An accuracy of the order of one day in 20,000 Martian years.
g) A date and time reference to the Roman calendar based on a Martian historical event, enabling any occurrance to be expressed in either system.
h) A computer program which prints calendars and generates monitor displays correlating Martian and Terran dates and times.
i) A distinctive nomenclature which precludes any possibility of confusion between the Martian and Terran chronometric systems.

And with these proud strokes of the word processor keys I thought I was finished writing this article. I had looked through every astronomy book about Mars I could find, but could uncover no more calendars. The next morning, in the last REM period before waking, I dreamt of a calendar in Robert A. Heinlein's 1949 *Red Planet*, a juvenile novel I had not read in 20 years. I bounded out of bed in the predawn gloom, flipped on the light in our study, and instantly found the book, for I had earmarked it for re-reading as part of the research for a future writing project of mine. Sure enough, in the course of a conversation in Chapter 1:

> Jim thought back over the twenty-four months of the Martian year. "Since along toward the end of Zeus, nearly November."
> "And now here it is the last of March, almost Ceres, and the summer gone."

Except for references to days of the week, named the same as the ones we know on Earth, Heinlein made no further mention of a Martian calendar, but the above passage proves that my invention of a 24 month Martian year, like many of the features in the Darian calendar, is not a new one under the Martian Sun.

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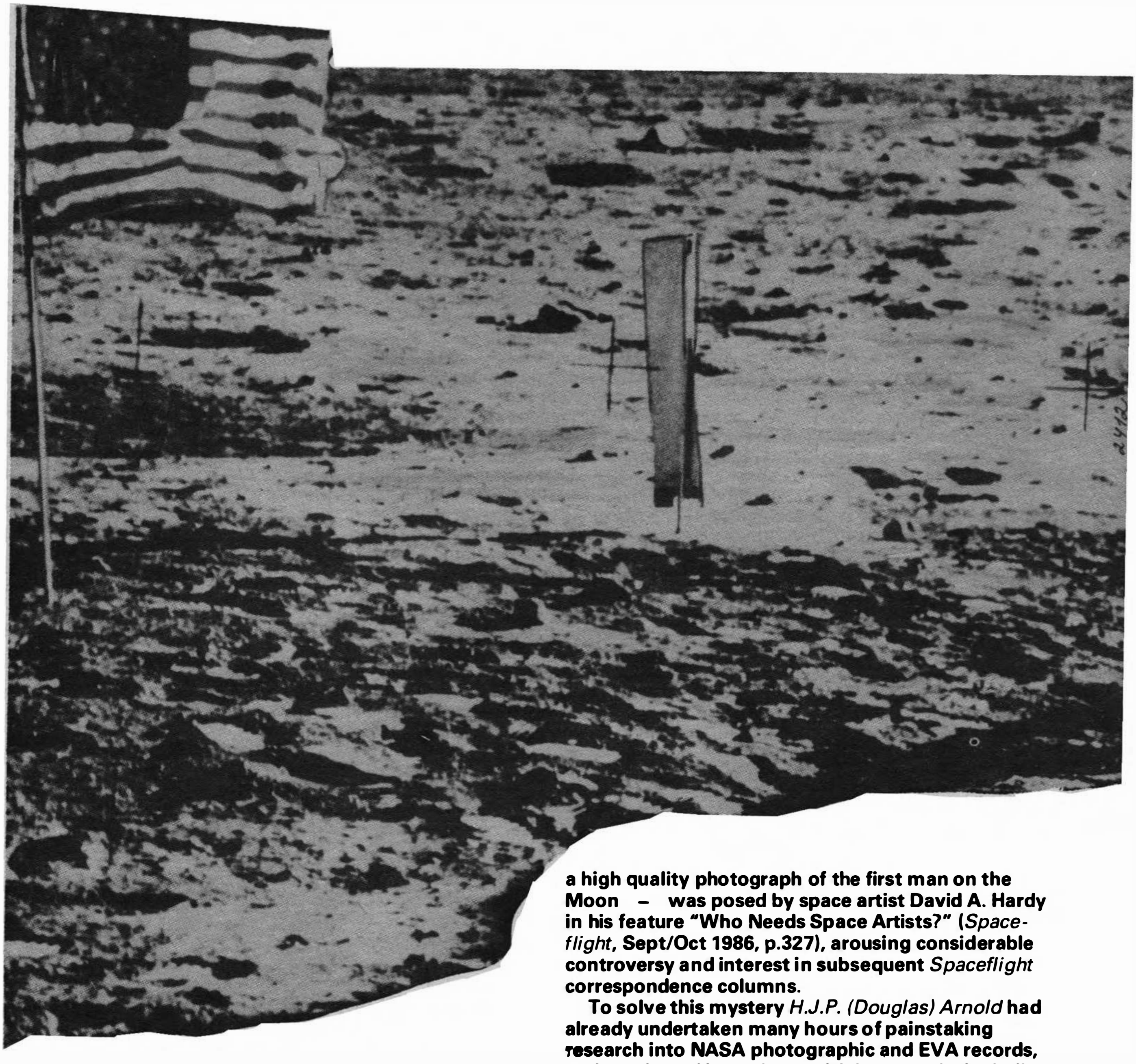
First Man on the



a high quality photograph of the first man on the Moon – was posed by space artist David A. Hardy in his feature "Who Needs Space Artists?" (*Spaceflight*, Sept/Oct 1986, p.327), arousing considerable controversy and interest in subsequent *Spaceflight* correspondence columns.

To solve this mystery *H.J.P. (Douglas) Arnold* had already undertaken many hours of painstaking research into NASA photographic and EVA records, and conducted interviews with key people, including the astronauts themselves. His investigation concluded last year and the result is an illuminating article which not only uncovers the only authentic, high quality photograph of Armstrong on the Moon, but also examines in fascinating detail the photographic aspect of lunar EVA activity, and the reasons why such an obvious and historic picture may have been overlooked.

by H.J.P. Arnold

How could it be that despite all the sophisticated planning and equipment, the Apollo 11 lunar landing mission returned to Earth without a high quality still photograph of Neil Armstrong on the Moon?

The intriguing question – is there or is there not

Moon

The Missing Picture

As he works at the MESA, Neil Armstrong is photographed by Aldrin· this identification after 19 years may be regarded as authoritative. (AS11-40-5886).

Introduction

The Apollo 11 mission took place almost two decades ago. For an increasing number of young adults as well as today's children, therefore, it is a matter of history – and not an event that was followed with rapt attention on TV as it happened. The first films brought back from the lunar surface inevitably had a quality which far surpassed the immediate television images and the standard of many of the photographs taken by Neil Armstrong during the EVA on the lunar surface using the newly introduced Hasselblad Data Camera (DC), while equalled occasionally, was never surpassed during any of the subsequent missions. When these classic images are examined in books and elsewhere today it is frequently assumed (and why not) that they show Neil Armstrong, the first man to walk on the Moon. Without exception, however, the high quality, original still images published hitherto have been of Edwin E. ("Buzz") Aldrin, the lunar module pilot (LMP), taken by Armstrong. Pictures of Neil Armstrong himself were taken either from the black and white TV record or as colour stills from the 16mm data acquisition camera (DAC) which was firing at a slow frame rate through one of the lunar module (LM) windows during the EVA. The quality difference between these derivative pictures and the Hasselblad images was inevitably enormous.

One of the great achievements of NASA from its beginnings has been to conduct its frequently dramatic affairs in the full glare of publicity – for good or ill. With an interest in space photography and imaging pre-dating the Apollo 11 mission, it had always puzzled this author that (apparently) no Hasselblad images of Neil Armstrong were taken during the EVA. This fact seemed to be borne out by an examination of the images released and discussions with photo-specialists at the Lyndon B. Johnson Space Centre in Houston. However, as long ago as October 1974 Neil Armstrong responded to an enquiry on this issue by writing [1] that the "70mm still camera requirements were shared with my share being about 75 per cent all according to the plan devised pre-flight for maximum utilisation of our limited time. I believe there is one picture with me in the background ....". Astronauts and former astronauts, no less than researchers and writers, all have livings to earn as well as having to devote time to more pressing and current events in the area of their chosen

Aldrin about to step off the LM ladder: Armstrong altered the Hasselblad controls to f/5.6 at 1/60th of a second for shadow photography. (AS11-40-5868).

First man on the Moon. Neil Armstrong prepares to step down to the lunar surface – a still from the TV record. (S69-42583).

interests. As a result it has taken until now to examine the subject of Apollo 11 lunar surface photography in some depth and to identify the one image of Neil Armstrong obtained with the single Hasselblad camera that was taken out onto the lunar surface.

Many of the participants approached shared their memories willingly – but the passing years have thinned their ranks and the memories themselves have tended to fade somewhat. Moreover, reflecting the pressure of events in 1969, contemporary or near-contemporary documents have to be analysed with some care also. Thus, the official NASA press kit for the Apollo 11 mission [2] stated that the lunar module would contain "two Hasselblad 70mm lunar surface superwide angle cameras" – whereas this specially developed model had been replaced in the photographic plan some months before by one of the newly introduced data cameras and one of the already flown Hasselblad EL (electric drive) cameras. This was an error that persisted at least as late as April 1970 when the Goddard Space Flight Centre published a Data Users' Note on Apollo 11 Lunar Photography [3]. In prospective or retrospective press releases Hasselblad AB itself referred to two of its cameras being taken out on the lunar surface (there was only one) – and of Armstrong taking all of the photographs exposed on the Moon, which was not the case [4].

The official NASA catalogue of Apollo 11 70mm photographs published early in 1970 [5] identified Armstrong as the astronaut descending the lunar module steps (it was, of course, Aldrin) and Aldrin himself wrote incorrectly in his autobiography [6] of a photo technician coming into contact with lunar dust on a film magazine and having to join those in the Lunar Receiving Laboratory (LRL) as a result, whereas the NASA technician had been in the LRL by design since before Aldrin and his colleagues arrived there. Sometimes the contemporary errors are a fit subject for humour – as with one of the very helpful NASA press conference transcripts [7] which referred to Apollo 11 astronauts taking "the magazine off the hazzle black camera"... which is phonetically close enough to "Hasselblad" to be instantly recognisable. These errors are not recounted in any spirit of superiority but in the hope that what follows has reduced the prolongation of contemporary errors to a minimum.

EVA Photographic Equipment

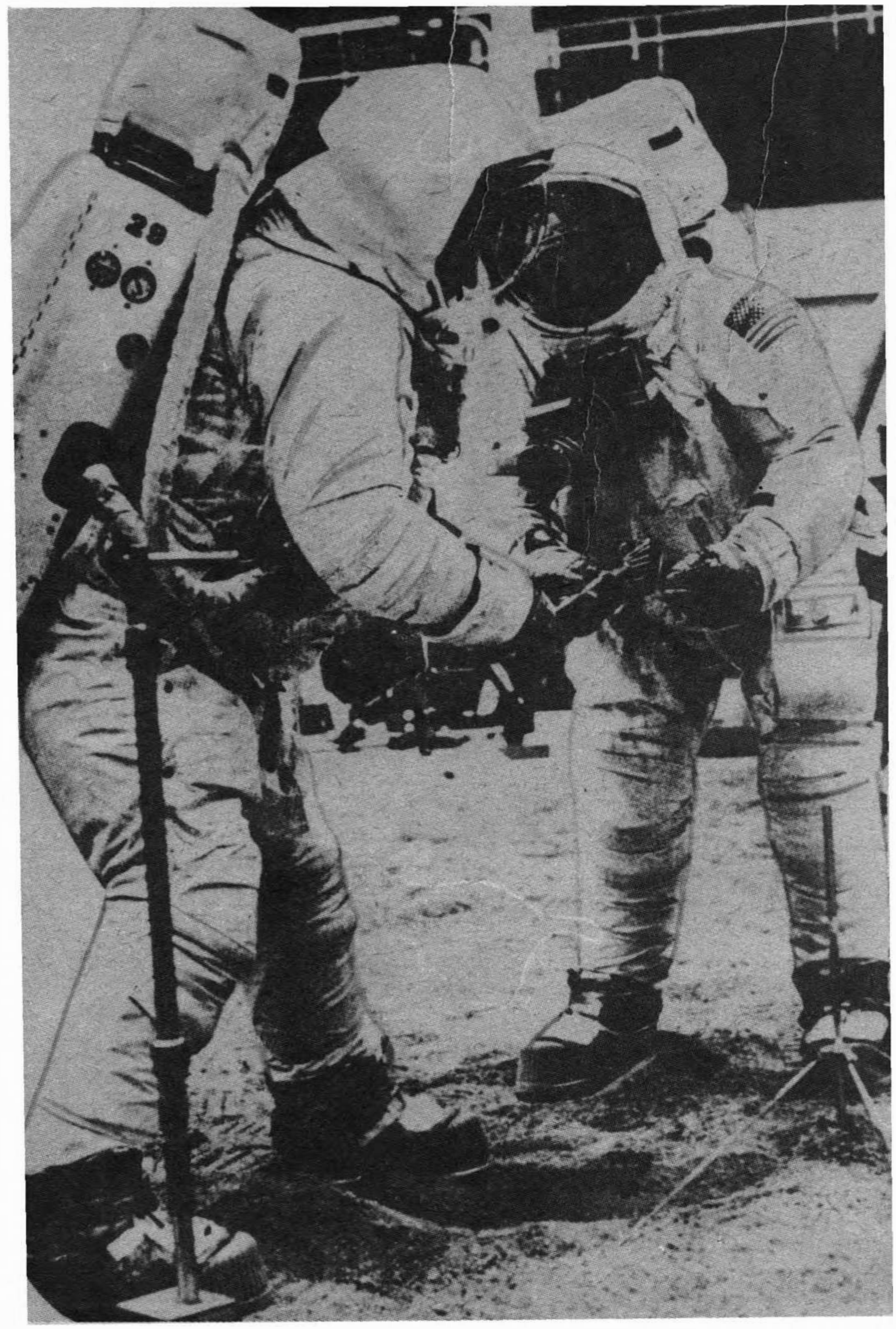
Two Hasselblad 70mm cameras were aboard the lunar module Eagle when it descended to the Moon's surface. What was by now established as the basic Apollo mission camera – the El – was a motor driven model that had been extensively modified partly to meet NASA's safety requirements following the Apollo 1 tragedy and partly to facilitate astronaut operation e.g. large tabs on controls. The camera's reflex system had been removed, it was fitted with an 80mm focal length f/2.8 Zeiss Planar lens and when loaded with Kodak thin-base colour films its magazines permitted up to 160 exposures per loading. This camera first flew in space on the Apollo 8 mission in December 1968.

During the Apollo 11 mission, the EL was used from within the lunar module only – to record Columbia at separation, the lunar surface from orbit, the scene around Eagle on the surface and a small number of images of Armstrong and Aldrin. The film used was Kodak Ektachrome SO168 – a film sensitometrically similar to the then generally available High Speed Ektachrome. The speed rating of 160ASA(ISO), together with its inherent lower contrast characteristics, resulted in its becoming the standard lunar surface colour film during Apollo. The Apollo 11 colour magazine used with the EL was designated by the code letter "R" pre-flight and the images exposed were subsequently given the magazine number "37" – thus AS11-37-5528, the latter being the individual frame identity number. This camera would have been used during the EVA if a fault had developed in the Hasselblad Data Camera. (A magazine of high resolution black and white film was also exposed through the windows of the LM.)

The DC was developed by Hasselblad for NASA in time to fly on

Apollo 11 and to replace the previously designated lunar surface Hasselblad super wide camera. Basically it was an EL model but with some significant modifications. In front of the magazine it incorporated a Reseau plate to facilitate the photogrammetric analysis of images (this caused the crosses seen on EVA photographs) and was used exclusively with a 60mm f/5.6 Biogon lens which Carl Zeiss had developed in only six months. Externally the camera had silver anodised trim (to help limit the effects of high lunar surface temperatures) and in order to free the hands of astronauts during extravehicular activities it was usually bracket mounted on the RCU – the remote control unit worn on the chest through which space suit environmental conditions were monitored and modified by the crewman. Neil Armstrong himself played a considerable part in the design and development of this bracket [8].

Exposures were made either by squeezing a large release plate at the front of the camera battery compartment or the trigger on a pistol grip when this was fitted. In the absence of a viewing system or frame, the astronaut had to depend on the wide angle field of view of the 60mm lens and his own good judgement both as regards desired coverage of subject matter and focussing to achieve good results. Exposure information on nominal aperture settings according to Sun position for the 1/250th of a second shutter speed normally selected appeared on small decals fitted to the camera. The Apollo 11 DC was loaded with SO168 film and was lowered to the lunar surface by means of the LEC – the lunar equipment conveyor, which was a line or pulley arrangement between the lunar module door and the surface. This necessitated film magazines being fitted with a tether ring. At the conclusion of the lunar surface EVA, the magazine of colour film was detached from the camera and the latter with its lens was discarded. (The Hasselblad EL camera aboard the lunar module was also subsequently discarded.) The EVA magazine was designated preflight by the code "S" and after processing the film was given the magazine number 40.



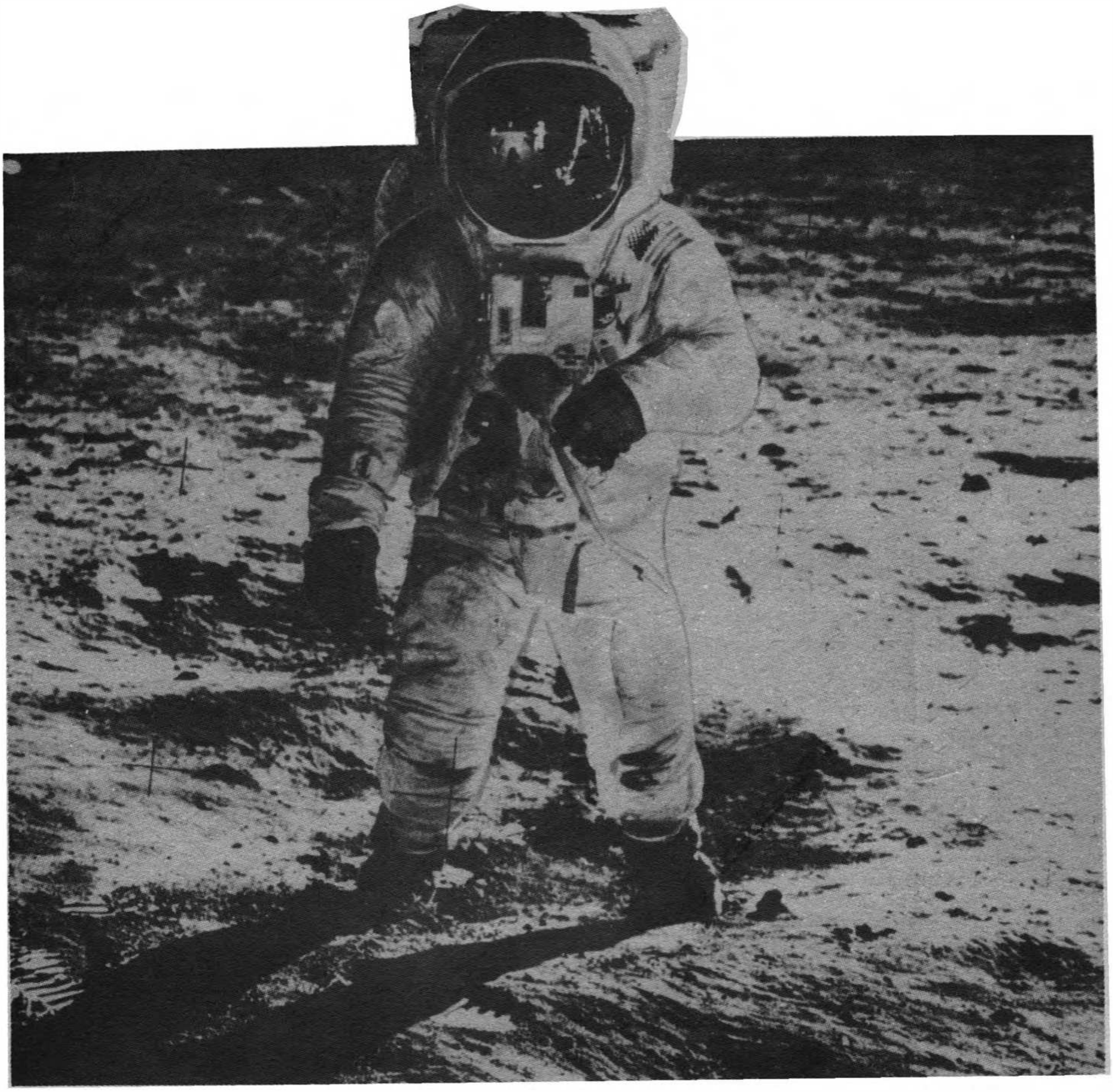
Armstrong (right) and Aldrin in training: note how the Hasselblad is mounted on the mission commander's RUC or chest pack so that both hands are kept free.

At all stages of the mission valuable engineering, operational and scientific information was derived from the 16mm Maurer Data Acquisition Camera. One of these cameras operated in the command module and a second in the lunar module where it was fitted to look through the right hand window. This was the camera which recorded the outside scene as Eagle descended to the lunar surface – and then the lunar surface activities by both crewmen. Buzz Aldrin had principal responsibility for its operation.

The DAC has often been referred to as a "movie camera" but this is a misnomer in that its basic purpose was to record a sequence of data images at frame rates which could vary from the conventional 24fps to 1fps – the slower frame rates giving the camera a high volume information capability when used in automatic mode. Thus at 1fps the standard magazine containing 130-140 ft of thin base colour film lasted for some 90 minutes. The Maurer had a number of features not found on more conventional movie cameras including completely independent shutter speeds and frame rates, an internal heater and a green light which pulsed at the frame rate chosen. Six magazines of S0168 Ektachrome 16 mm colour film were aboard Eagle and the camera was fitted with an 18mm wide angle lens.

Aldrin was required to alter the DAC framing rates at various stages of the EVA and these may be studied in Figure 1 where the Maurer is referred to as "SC" (for sequence camera). It is difficult to check accomplishment against the plan but the result was generally satisfactory and the air to ground voice transcription records, for example, Aldrin's concern to achieve correct aperture and shutter speed settings for the DAC as Armstrong was descending the ladder in heavy shadow [9]. Subsequent frames were to play an important role in the situation which is to be discussed and analysed below.

Although not directly concerned with the subject of this paper, it is appropriate to note that Eagle also carried to the lunar surface a close up camera (ALSCC) built by Eastman Kodak. This was a stereo camera with integral electronic flash that took pairs of pictures on 35mm colour film of areas of the lunar surface measuring



Neil Armstrong's classic 'visor' photograph of Buzz Aldrin. (AS11-40-5903).

3 in sq. These images were intended to characterise the structure and texture of the loose, fine grained material composing the upper surface of the lunar crust before any disturbance by astronaut movements and geological specimen retrieval. Seventeen dual images were obtained by Armstrong and Aldrin and the distinctive shape of the ALSCC is clearly seen in a number of the Hasselblad EVA frames [10].

The command module Columbia was also supplied with a Hasselblad EL and a Maurer DAC and good use of these was made by command module pilot Mike Collins – and his colleagues at times other than the lunar surface EVA. The concentration of this paper on the latter subject is no reflection on either the importance or quality of the photography from the command module.

EVA Photographic Plan

In general virtually all of the photography was aimed at documenting activities at major stages of the mission whether in orbit or on the lunar surface. During the EVA, such coverage was required to establish the condition of the lunar module – particularly its four struts or legs, the effect of its descent engine plume on the lunar surface, the interaction between the lunar surface and the astronauts' boots, to record panoramas around the LM location, and to aid in documenting geological specimens noted or collected. This was in addition to recording the deployment of the experiments set up on the lunar surface – the solar wind composition experiment (SWC), the passive seismic experiments package (PSEP) and the laser ranging retroreflector (LRRR).

To avoid lengthy detailing of the photographic activities on the surface, the seven pages of the appropriate section of the operation plan [11] are reproduced here as Figure 1. For those not conversant with such plans, it may help to point out that each sheet shows two sequential sections of the plan for commander (CDR) and LMP side by side with times at 10 minute intervals indicated and with tick marks at one minute intervals. All photo activities have been highlighted by the author with single margin marks but those of particular significance are accorded triple marks.

A calculation based on the plan indicates that Neil Armstrong's comment that he operated the Hasselblad camera for around 75 per cent of the time was approximately correct. A major feature of the plan was that Armstrong was required quite specifically to photograph Buzz Aldrin (LMP) on three separate occasions – at 0.41 minutes, 1.39 minutes and 2.14 minutes respectively quite apart from documenting activities that Aldrin was conducting. In fact Armstrong photographed Aldrin (or Aldrin is in the scene) on no less than 28 occasions out of the total of 128 frames on the film. (One image that he did not secure was the third required above – of Aldrin ascending the LM steps at the conclusion of his EVA.) *At no time during the approximately 25*

minutes that he was scheduled to have the Hasselblad during the EVA was Aldrin required by the plan to photograph Neil Armstrong – at a time when the mission commander was collecting the geological bulk sample, taking close up photographs and examining the condition of various parts of the LM.

Post-Mission Events

The release of the historic photographs for which the media of the world were waiting was planned well in advance and proceeded efficiently despite the inevitable complications imposed by the quarantine regulations that covered the early Apollo lunar landing missions [12]. All films (together with the lunar rocks) arrived at the Lunar Receiving Laboratory at the then Manned Spacecraft Centre on July 25 1969. This was ahead of the crew.

The film magazines (sealed in plastic containers) had already been through a decontamination lock containing a solution of sodium hypochloride aboard the mobile quarantine facility. As soon as possible after arrival in the LRL, the films were exposed to a fumigant-sterilant gaseous solution of 12 per cent ethylene oxide and 88 per cent dichlorofluoromethane for a period of 16 hours in an autoclave chamber. The films then remained in the decontamination system for a further 24 hours awaiting the possible growth of bacteria on accompanying control strips. When no such growth occurred, the films were released to the Photographic Technology Laboratory for processing. The decontamination procedure had been carefully checked in advance but several days before the flight films arrived a test film was ruined: the cause was immediately found and a modifiction to the equipment resulted in the subsequently safe treatment of all mission films.

The Photographic Technology Laboratory at MSC was by this time one of the most advanced processing units in the world – but there was still some debate about the handling of the Apollo 11 films once they had been released from the LRL. Overall responsibility was that of John R. Brinkmann chief of the PTL but the task of processing the films was in the the hands of Richard W. Underwood at that time in charge of the PTL's precision laboratory. A proposal had been made that for safety reasons the lunar surface films should be cut up in pieces and processed individually thereby ensuring the survival of at least some film should a disaster occur. This was rejected by Brinkmann and Underwood [13] but a plan was agreed with public affairs and other staff for the decontamination and subsequent processing of films to be separated into two batches of 70 mm and 16 mm film – with the lunar surface EVA film (magazine S) in the second batch, for obvious reasons. This plan was facilitated by the flight crew noting the priority magazines – and Buzz Aldrin was said to have been particularly helpful in this [14].

Underwood, two NASA PTL colleagues and contractor support staff from the Data Corporation started processing the first films on the evening of Sunday July 27, 1969 in modified Kodak Versamat equipment. Elaborate safety and control procedures were in force and the film was checked at several stages by infrared inspection. The initial preparation and processing run took approximately seven hours. Shortly thereafter the initial media release selection began at the PTL with members of MSC management and Brian M. Duff (head of public affairs) present.

An examination of press cuttings from the US daily printed media shows that the schedule planned in advance by NASA public affairs staff was largely realised. The first still images caught the evening newspapers of Tuesday July 29 and the morning editions of July 30: a frame from magazine R showing the US flag, the outline of an LM thruster and bootprints on the lunar surface was the most frequently reproduced image. (Interestingly, it was accompanied in many newspapers by new images of Mars sent back by the Mariner 6 fly-by spacecraft.) Views from orbit followed and then by Friday August 1 stills of lunar surface activities from the 16 mm DAC (including Armstrong) and some of the classic Hasselblad images of Aldrin photographed by Neil Armstrong were being seen everywhere. The first colour clip from the DAC (of the descent of Eagle to the lunar surface) was transmitted on television on the evening of July 29.

The picture selection process from Monday July 28 and on over the next few days raised a problem central to the subject of this paper. Brian Duff had returned to the MSC as head of public affairs ten weeks before the first lunar landing when he replaced Paul Haney. He was immediately pitched into handling media affairs for the Apollo 10 mission in May 1969 and could scarcely take breath before Apollo 11 was launched. Almost eighteen years later he recounted [15] the hectic session in the PTL at which the first 70 mm and 16 mm films were examined (though presumably this was typical of a number of sessions as the batches of films became available):

> Everyone was yelling and everyone had a candidate. Finally, someone – I hope it was me – said "shouldn't we try to get a picture of the first man on the Moon?" That settled things down and we started looking for the best 70 mm shot of Neil. Soon we were looking for any shot of Neil. Finally George Low, the Apollo manager, or Bob Gilruth, the Center Director, suggested I call Neil and ask him ... I have a very strong memory of the phone call. I felt it was a very great presumption to awaken Armstrong in the LRL with such a question but it was obviously necessary.
>
> I remember saying: "Neil, this is Brian. When did you give the camera to Buzz?" I distinctly remember him saying: "I never did", I said "Thanks" ... and hung up. I told the others and we concentrated on the best possible picture of Buzz...
>
> I am certain of what he [Neil] told me in the Lab ... we poured over every bit of film in the days that followed. There would have been no hesitancy in relesing a photograph later if we had found one. I don't think any usable photography of Armstrong exists other than [stills from] the 16 mm motion picture photography ...

In retrospect it is clear that Neil Armstrong either misunderstood Duff's question or answered it pedantically for the operations plan did not call for him to *give* the Hasselblad to Buzz Aldrin but to place it on the LM MESA (modularised equipment stowage assembly) – see the plan timeline for 0.53 minutes – though the plan makes no specific reference to Aldrin picking up the camera. In the air-to-ground voice transcription Aldrin made several references to using the camera (see below) and at 04.14.52.01 mission elapsed time said: "And, Neil, if you'll take the camera, I'll get to work on the SEQ bay" [16].

Thus there is no doubt that Buzz Aldrin used the Hasselblad although Brian Duff's account above is one element in the belief held by informed members of the Johnson Space Centre to this day that no original, still image of Armstrong was taken during the EVA. Subsequent events made any analysis of the situation difficult. After a non-stop series of post-mission briefings, the crew was released from quarantine on August 10. A general press conference was held two days later following which a number of domestic US trips were made by the astronauts, including visits to home towns, the White House and the Congress before which each astronaut delivered an address. On September 29 they and their wives left on a 45 day world tour to twenty seven cities in twenty four countries. The demands made on them thereafter continued at an intense level, although each at a fairly early stage appears to have decided that the future lay outside NASA. Preparations for the Apollo 12 mission in November 1969 were already proceeding apace so work pressures on members of the MSC staff and the problem of the availability of the Apollo 11 crew, particularly to deal with matters of what seemed detail, presumably accounted for the issue not being resolved at that time.

Irrespective of the passage of time, the fact remains: Buzz Aldrin had the Hasselblad – so did Neil Armstrong appear in any of the images taken?

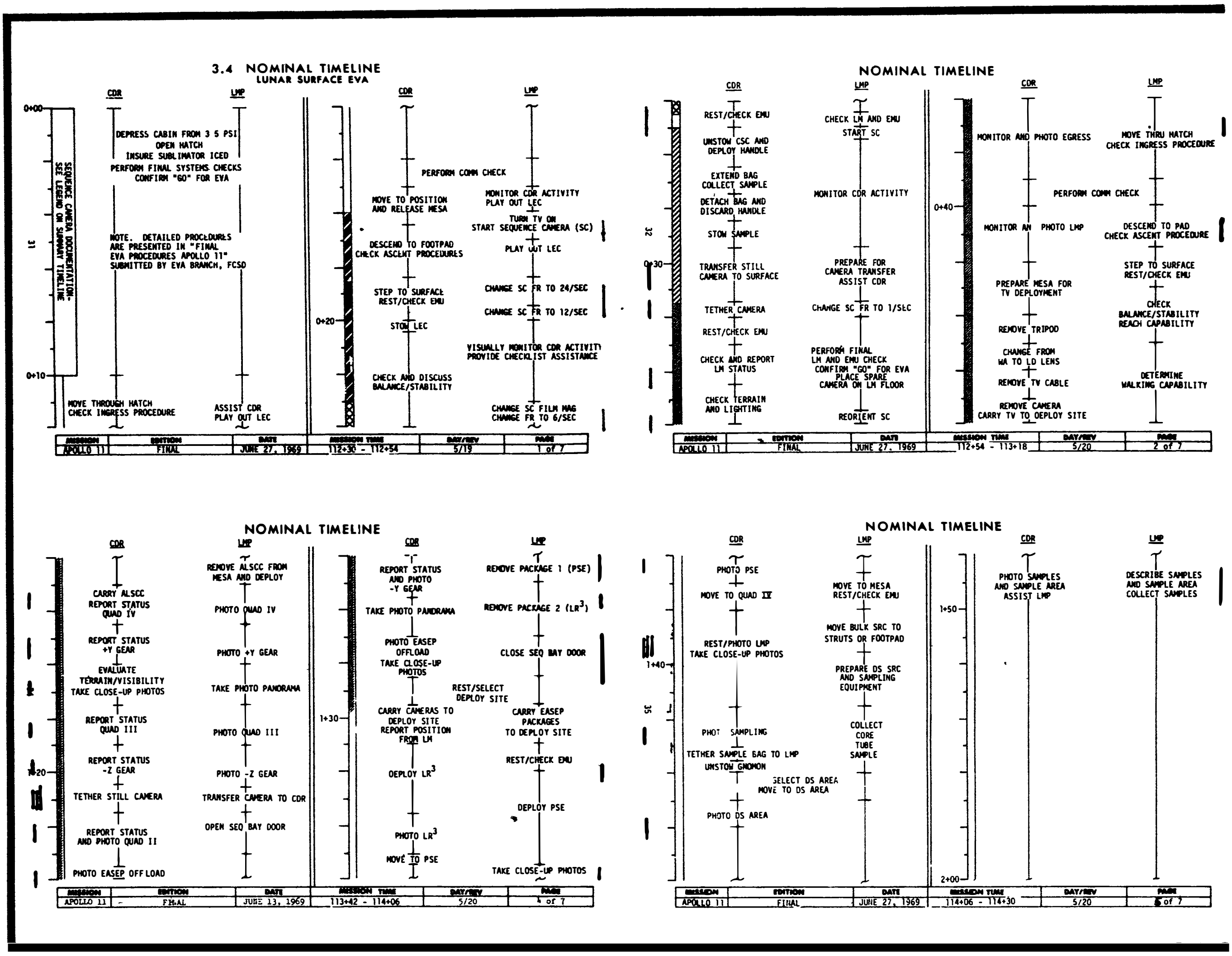


Fig. 1. Apollo 11 lunar surface operations plan.

Analysis

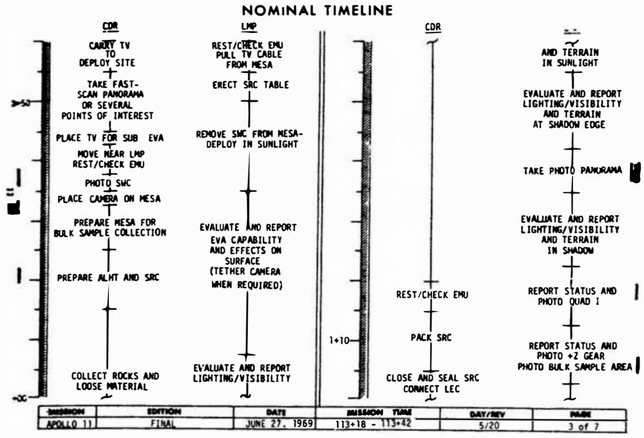
A 70 mm film strip of all of the images exposed using Hasselblad magazine 40 on the lunar surface has been examined closely and at length. Supplementary information was derived from the TV and sequence camera film records – and by a study of the operations plan as well as the air-to-ground voice transcript, both of which have already been noted. The operations plan is, of course, a record of intention and not of fact but it provides a valuable framework for analysis. Most importantly, copies of all relevant images were submitted to Neil Armstrong and Buzz Aldrin during the course of 1987 and their responses were obtained in writing in the former case [17] and by telephone in the latter [18].

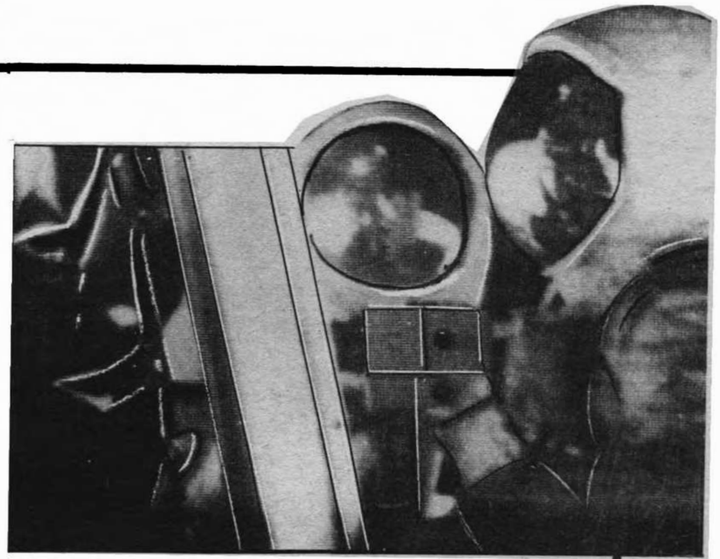
The nominal timeline (Figure 1) shows Aldrin taking up the Hasselblad camera at approximately 0.55 minutes into the EVA and relinquishing it at 1.21 minutes. Intended subject coverage during this period may be seen from the timeline. A more detailed description of the intended operations [19] refers to a soil mechanics study in which Aldrin was to take a stereo pair of "boot penetration" and then of "adhesion (photo boots)." While not appearing in the nominal timeline these images are readily located as frames 5876-5880. Frame 5876 is a photograph of an undisturbed area of the lunar surface requiring the Hasselblad to be pointed straight down at right angles. Frames 5877 and 5878 are views of a single bootprint from slightly different angles (the required "stereo pair") while 5879 and 5880 are different views of a boot showing part of a print to the right side. Both astronauts have confirmed this image sequence as having been taken by Buzz Aldrin, who also stated that the Hasselblad was hand-held and not mounted on the RCU – an obvious requirement to enable the camera to be pointed directly downwards. Since frame 5875 has been reliably identified as Aldrin standing by the US flag, *frame 5876 may be regarded with complete confidence as marking the commencement of the LMP's use of the Hasselblad.*

The detailed operations plan called for Aldrin to examine and photograph the plus-Z strut in some detail and that strut (showing the commemorative plaque) is the subject of frames 5897-5900. Buzz Aldrin believes he did not take these photographs so his last Hasselblad image on the lunar surface is in doubt. It must be somewhere between frames 5892 and 5901 (fortunately this point is not too critical) since frame 5902 is one of the classic images of Aldrin photographed by Armstrong, who retained the camera thereafter [27].

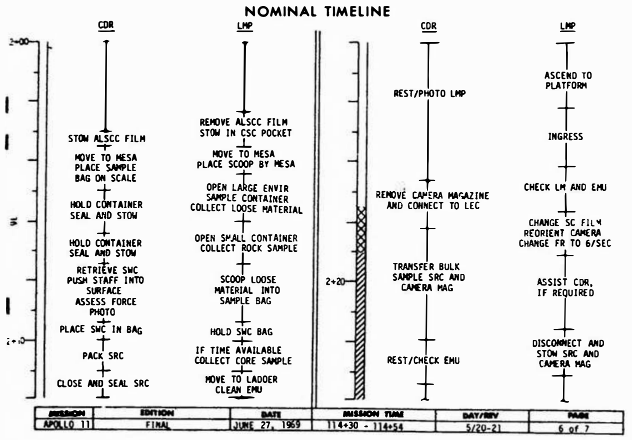
Discussion

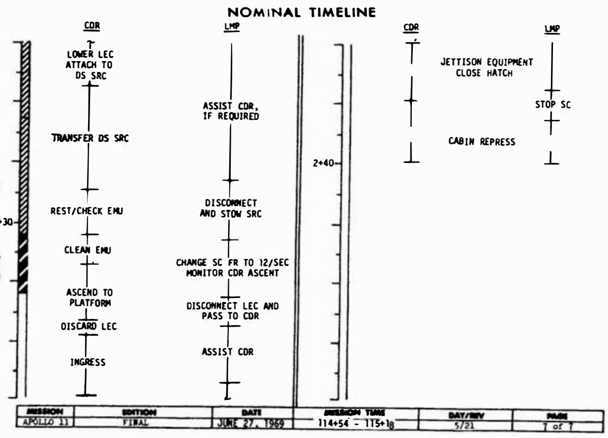
In Apollo 11 everything was subordinated to the requirement that two men should descend to the lunar surface and return safely into lunar orbit and thence to the Earth. At one time it appeared that only one crew member would make an EVA for a short period of time to gather rocks and that no experiments would be deployed. [28] In the event the two crew members conducted an intensive programme of activities which allowed no spare time or idle sight seeing in an EVA period of slightly over 2 hours 40 minutes. Both astronauts referred subsequently to these demands in their different ways – Aldrin stating that "(my) strongest memory of those few hours as the first men on the lunar surface was the con-





Aldrin and Armstrong from the TV record. The NASA caption identifies Armstrong at left but this appears to be an error since Buzz Aldrin states he never wore the camera on his chest. (S69-39563).





stant worry that we'd never accomplish all the experiments we were scheduled to do. Philosophy and emotion were not included and, in fact, were discouraged" [29] while Armstrong referred to there being "a lot of things to do and we had a hard time getting them finished ... We had the problem of the five year old boy in a candy store. There are just too many interesting things to do" [30]. Towards the end of the EVA, mission control was estimating ten minutes only for the documented sampling of lunar rocks so it was little wonder that the astronauts later noted that the sampling was conducted very rapidly with "no attempt ... made to actually document the samples by voice or photography." [31]

As Mercury became Gemini and Gemini developed into Apollo the photographic programme for crews (expressed in greatest detail in a photographic and TV procedures document) became ever fuller and more tightly structured. The overwhelming emphasis was on operational, engineering and scientific documentation photography but nonetheless many fine "news" images were obtained on missions. Brian Duff has given [32] an intriguing insight into securing these:

> It is .. misleading to think that everyone in NASA agreed about the importance of public affairs or public affairs photography. Part of the "right stuff" image was not to care about that sort of thing and the only argument which worked was to equate it with "continued Congressional support". From the outside it may have looked like a well-oiled machine but on the inside it was what I call "creative tension". My recollection of those days is a constant battle with my friend Deke Slayton and other engineeers, scientists and astronauts to get another small concession to "public affairs photography" for "my friends in the press". It may surprise you to know that it was necessary to demand that colour film be carried to the Moon on Apollo 11. It was not considered "scientifically accurate" in its ability to depict colour and monochrome film was specified. Only when it was asked whether NASA could accept a black and white photograph of the first man on the Moon on the cover of LIFE was it agreed to include a quantity of colour film.

Notwithstanding this, Duff indicated (33) that the demands of the media were usually met:

> For most of us the eventuality of getting no pictures of either [Aldrin or Armstrong] was unthinkable. You will be horrified to hear this, I know, but those kind of "touristy" snap shots were not programmed into the time line. They were supposed to be taken as a matter of course in among the "scientific" or "documentary" photography. And they almost always were. If we missed great human interest shots, and we almost certainly did, we probably were not the wiser.

There was, in fact, something of a paradox here because, while the astronauts always stressed the need to meet mission requirements (whether in photography or elsewhere), in their comments they were not slow to mention more popular forms of photography. Thus Buzz Aldrin referred [34] to both scientific photography "and standard home pictures for the folks back on Earth" being taken during his Gemini 12 EVA in 1966 – and exiting the LM during the Apollo mission "to join Neil, who, in the tradition of all tourists, had his camera ready to

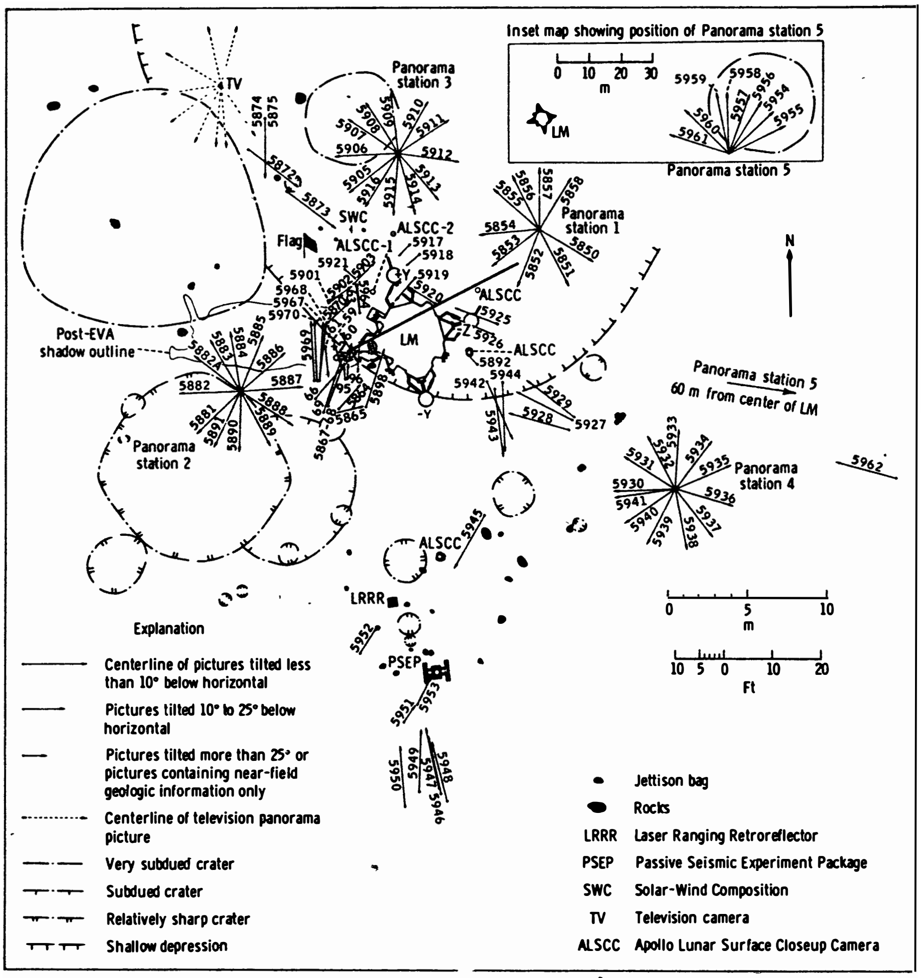


Fig. 2. Preliminary map of EVA photographs and TV pictures taken at Apollo 11 landing site.

photograph my arrival".

Michael Collins recounted [35] how, when the crew entered lunar orbit and saw the Earthrise, it was a "truly dramatic moment that we all scramble to record with our cameras" – and how, after the TEI burn on the return journey, "we whip out our cameras and start taking pictures of the lunar surface, just like tourists leaving Venice who suddenly discover they have three rolls of film left". Astronaut Don Lind made a humorous comment on the subject [36] when commentating on a training film of Armstrong and Aldrin at a pre-mission briefing: "They change [the Hasselblad] about the time they start the LM inspection. The reason for that is that then both of them get pictures taken of themselves. No, the real reason is that it balances the work load ...."

While it has been demonstrated reliably that one Hasselblad image of Neil Armstrong does exist, this picture – together with stills from the sequence camera films – compares unfavourably with the numerous splendid images that Armstrong took of Aldrin. The latter addressed this fact in his autobiography: "As the sequence of lunar operations evolved, Neil had the camera most of the time, and the majority of the pictures taken on the Moon that include an astronaut are of me. It wasn't until we were back on Earth and in the LRL looking over the pictures that we realised there were few pictures of Neil. My fault perhaps but we had never simulated this in our training ... every minute was busy." Aldrin recounted being photographed by the US flag and then preparing to change positions with Armstrong so that he could be similarly photographed when mission control announced that President Nixon wished to speak with them. After that, they went on to other activities [37].

At approximately 1.05 into the EVA the nominal timeline requested a photo panorama and the detailed plan [20] a "12 photo panorama (from position 20 feet in front of the +Z pad)" (this is the LM strut or leg bearing the ladder). At 04.14.31.29 elapsed time, the voice transcript records Aldrin as saying "The panorama I'll be taking is about 30 or 40 feet out to ... the plus-Z strut". [21] This panorama occupies frames 5881 to 5891 – with an additional frame within the sequence identified as 5882A yielding precisely the requested twelve photographs. The Preliminary Science Report [22] published after the mission reproduced a mosaic of this panorama on pages 104/5 and identified it as the second of five panoramas taken. It was also placed on a map of the site containing the location of most of the frames exposed in the Hasselblad. This map is reproduced here as Figure 2. A second map in the Report [23] showed a "recovered" trail for Aldrin close to this panorama viewpoint.

Of major importance in this panorama is frame 5886 which shows an astronaut working in the MESA area of the LM with the +Y strut and the US flag with the SWC staff off to the left. This must be Neil Armstrong – an identification substantiated by the fact that for part of this period he was working at the MESA whilst collecting the bulk geological sample, which the second PSR map referred to above confirms was located in the precise area shown in this frame. Since Neil Armstrong's records were in storage at the time of these enquiries his confirmation of frame 5886 as being that to which he referred in original correspondence was decribed as being "without guarantees" but Buzz Aldrin was in no doubt whatsoever. *The frame may therefore be identified reliably as being the only Hasselblad frame of Armstrong on the surface.* It may also be added that while for obvious reasons this frame has been little requested over the years, it is now identified to enquirers by picture research staff at NASA's Johnson Space Centre as being of Neil Armstrong.

A post-EVA portrait of Armstrong in the LM by Aldrin. (AS11-37-5528).

Subsequent to the panorama are ten frames of parts of the LM as requested by the nominal timeline though other than a tentative photo reconstruction is difficult. At 04.14.34.13 elapsed time Aldrin reported [24] that he was near the minus -Y strut taking some photographs and this strut appears as frame 5892. He subsequently referred to getting some pictures of the "aft part of the LM" and then made an ambiguous comment about a panorama. [25] At 04.14.48.04 he reported photographing the plus -Y strut (his words are mistakenly attributed to Armstrong in the transcript) and this subject does appear in frame 5901. A few minutes later he mentioned having taken a "stereo pair" of one of the pads: this does not appear in the transcript but was deciphered from the tape of the EVA. Frames 5895/6 could well be this pair. At 04.14.52.01 the Hasselblad was handed back to Armstrong [26].

While Aldrin's explanation about not having "training" to photograph Armstrong may seem thin to outsiders, other more outward going astronauts have confirmed the constant race against time during a lunar EVA and the intense drive to meet mission requirements [38]. Some NASA employees and other correspondents have speculated whether the absence of pictures of Armstrong reflected pique on the part of Aldrin at not being first on the lunar surface – a matter that received considerable attention in the US media in the spring of 1969. This seems most unlikely for, as we have seen, Aldrin was concerned about optimum settings on the DAC to record Armstrong's descent downthe LM ladder and his initial activities on the lunar surface – and also took an excellently observed portrait of Armstrong in the LM after the EVA. These actions are scarcely compatible with the alleged attitude.

Neil Armstrong's own attitude is equally interesting. He was clearly not concerned with being photographed or, if he were, considered it improper to demonstrate such feelings. We may speculate that the "right stuff" requires that an event be performed well, and for it to be known to one's peers that such is the case – but that recording the occasion on film is of no consequence. Armstrong's subsequent attitude to researches of the kind on which this paper is based is consistent with this attitude: a courteous prepardness to help as far as possible but with a slightly amused inability to comprehend why anybody should be interested in such irrelevant details. This presumably accounts for the fact that, after the Apollo 11 mission, Armstrong (and the same is true of Aldrin) appear at no time to have enlightened public affairs staff at MSC as to the existence of a Hasselblad image of the mission commander on the lunar surface – which, while not markedly superior to the sequence camera stills, at least provided a different view point.

Another aspect of this matter concerns the US media. It is the most demanding in the world but at no time does any correspondent seem to have asked why the picture releases of Armstrong were so poor compared with those of Aldrin. This would not have concerned the television channels for which the DAC clips were most suited but the printed media might have been expected to raise the issue. A possible explanation is that the staggered release of images resulting from the quarantine demands, taken with all the other activities such as the fast approaching Apollo 12 mission, limited awareness and therefore any consideration of picture quality per se.

Conclusion

It remains perplexing why the lunar surface operations plan did not call for Buzz Aldrin to take any photographs of Neil Armstrong. If that plan could require Armstrong specifically to take

three photographs of the LMP as well as of procedures in which Aldrin was involved (and so would figure in the images), in the admittedly much shorter time that Aldrin had the camera it would seem equally valid for Armstrong's collection of the bulk sample and a record of the mission commander working at the MESA to be regarded as valid subjects for a series of "operational" photographs. There seems little doubt that if such requirements had been placed in the operations plan then Aldrin would have obtained photographs of considerably better quality than the sequence camera stills.

In retrospect it is easy for the researcher to take a measured look at the failure to obtain high quality images of Armstrong and to criticise public affairs staff (as well as mission planners) for not realising the likely outcome. This point was made to Brian Duff who responded frankly [39]:

> [The realisation] was not likely to happen in the supercharged atmosphere of the first lunar landing. I for one could hardly believe we were getting past one incredible hurdle after another. The astronauts were on the surface of the Moon a relatively short time. They had a great deal to do and no one was about to ask them questions or ask them to do anything that was not absolutely necessary. If someone had realised what was happening we could have relayed a suggestion up to Neil to hand Buzz the camera, but no one did realise it. The communication from the surface was sparse on 11 compared with later missions. *And we all believed we were getting photographs of both men....*

And again later [40]:

> We simply did not spot the potential for missing good photography of Armstrong. If we had we would have asked that it be fixed through normal channels and it would have been fixed. Blame lack of attention; blame pressure of events; blame a presumption that procedures followed on earlier flights would be followed again. All contributed. There was no single fault ... it was a series of simple human oversights.

From Apollo 12 onwards both crewmen wore Hasselblad cameras on the lunar surface so each tended to appear in a considerable number of operational photographs – to say nothing about the time honoured flag saluting ceremony. On Apollo 12 Alan Bean, the lunar module pilot, was also specifically required to photograph the commander Pete Conrad with the Hasselblad as the latter egressed on to the LM porch and down the ladder [41].

From Apollo 13 (although the oxygen tank explosion aboard the service module on that mission precluded a descent to the lunar surface) the problem of identifying the two astronauts during the EVA was solved by the provision of broad red bands on the arms, legs and helmet of the commander's EMU (space suit). This problem had been raised on a number of occasions from Apollo 11 onwards but the earliest document located on the matter is a memorandum dated December 10 1969 from Julian Scheer, assistant administrator for public affairs at NASA HQ in Washington, to James McDivitt, manager of the Apollo spacecraft programme at MSC at that time. A number was one suggestion made but Scheer expressed a preference for "some kind of armband". Apparently McDivitt had some objections but the MSC Director Gilruth favoured the proposal [42] and it was implemented within a matter of weeks.

* * *

There is no need here to stress the magnitude of the Apollo achievements – and particularly those of Apollo 11 and every individual associated with its success. An estimated audience of more than 500m citizens of the world witnessed Neil Armstrong's descent down the LM ladder and the subsequent events as they were televised in "real time". In that sense all of us who watched were privileged onlookers in an experience given to none but immediate participants of earlier, equally historic, events.

But time passes and, as permanent records, stills from the television transmission provide little more than "atmosphere" – while frames from the DAC or sequence camera have inevitable deficiencies in portraying the activities of the first man to walk on the Moon. A Hasselblad frame showing Armstrong has now been reliably identified but it cannot compare with many of Armstrong's images of Buzz Aldrin. All too often, therefore, those seeking quality images to illustrate humankind's first departure from the bounds of Earth show Aldrin – sometimes, at least, in the mistaken impression that it is Armstrong.

The emphasis on mission requirements as regards photography, astronauts' personal attitudes to the taking of "public affairs" photographs and Neil Armstrong's own lack of concern about being photographed with the Hasselblad are all understood – but on the occasion of the first lunar landing they should all have been subordinated to the need to secure some of the best possible images of Armstrong. NASA quite properly devoted time to consideration of symbolic activities to be performed on the Moon by Armstrong and Aldrin – and, indeed, a committee was set up to consider this matter [43]. In a like manner, it is evident in retrospect that more attention should have been paid to ensuring a high quality, symbolic record depicting the first human to walk on the surface of another body in the solar system – for the historical significance of the event transcended in importance all aspects of the technology that achieved it.

ACKNOWLEDGEMENTS

The author is indebted to Neil Armstrong and Edwin ("Buzz") Aldrin for responding to questions in a helpful manner which led ultimately to identification of the lunar surface Hasselblad photograph of the former Former astronauts Alan L Bean and James A Lovell also provided valuable detail and background information The flow of documents from Lee Saegesser of NASA's History Office in Washington and from David Compton, historian at the Johnson Space Centre, was considerable and seemingly without end This researcher – like many others – owes them a great deal Brian Duff responded willingly and fully to numerous questions and gave a vivid insight into the "atmosphere" of the summer of 1969 in Houston which almost certainly could not have come from any other source A long-time friend – Dick Underwood, formerly of NASA's Photo Technology Laboratory – also responded in his typically helpful manner by thinking back eighteen years to the dramatic hours at the laboratory when the lunar surface films were being processed

Others who gave assistance were two media "veterans" in the US, Roy Neal of NBC TV and writer Richard S Lewis, Les Gaver at NASA headquarters and former public affairs officer at MSC Paul Haney, and – inevitably – Mike Gentry and Lisa Vazquez of the Stills Photo-Library at the Johnson Space Centre who provided their customary speedy and efficient service Finally, an exchange of views with Keith T Wilson was helpful

Research of this kind is a continuous process and any additional information or corrections of inadvertent errors will be received gratefully by the author

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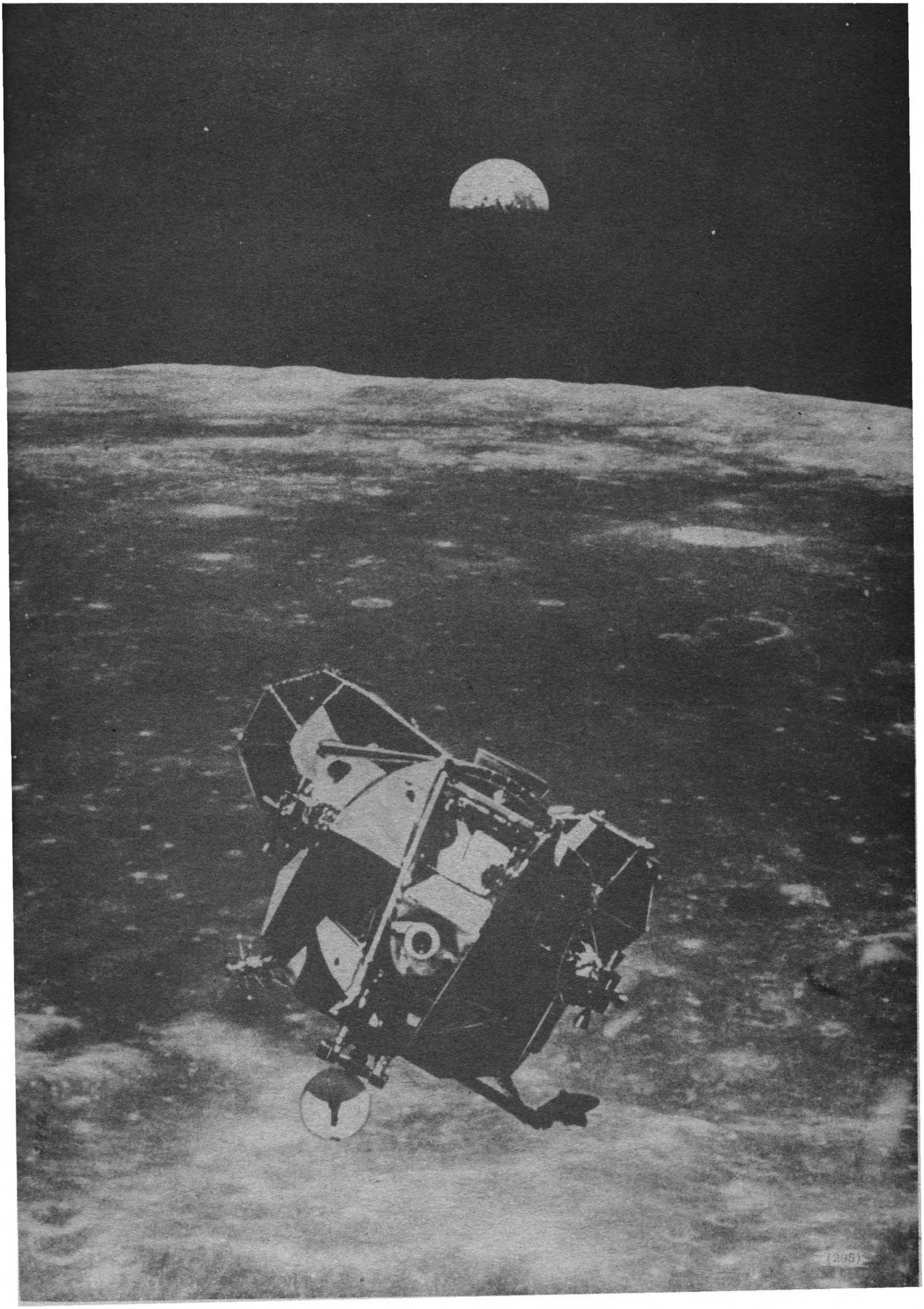
43 For example, see a memorandum on the subject to George Mueller (associate administrator for manned spaceflight) from Willis H Shapley, associate deputy administrator of NASA, April 19 1969

Right: Eagle ascent stage and Earth recorded from Columbia by Michael Collins. (AS11-44-6642)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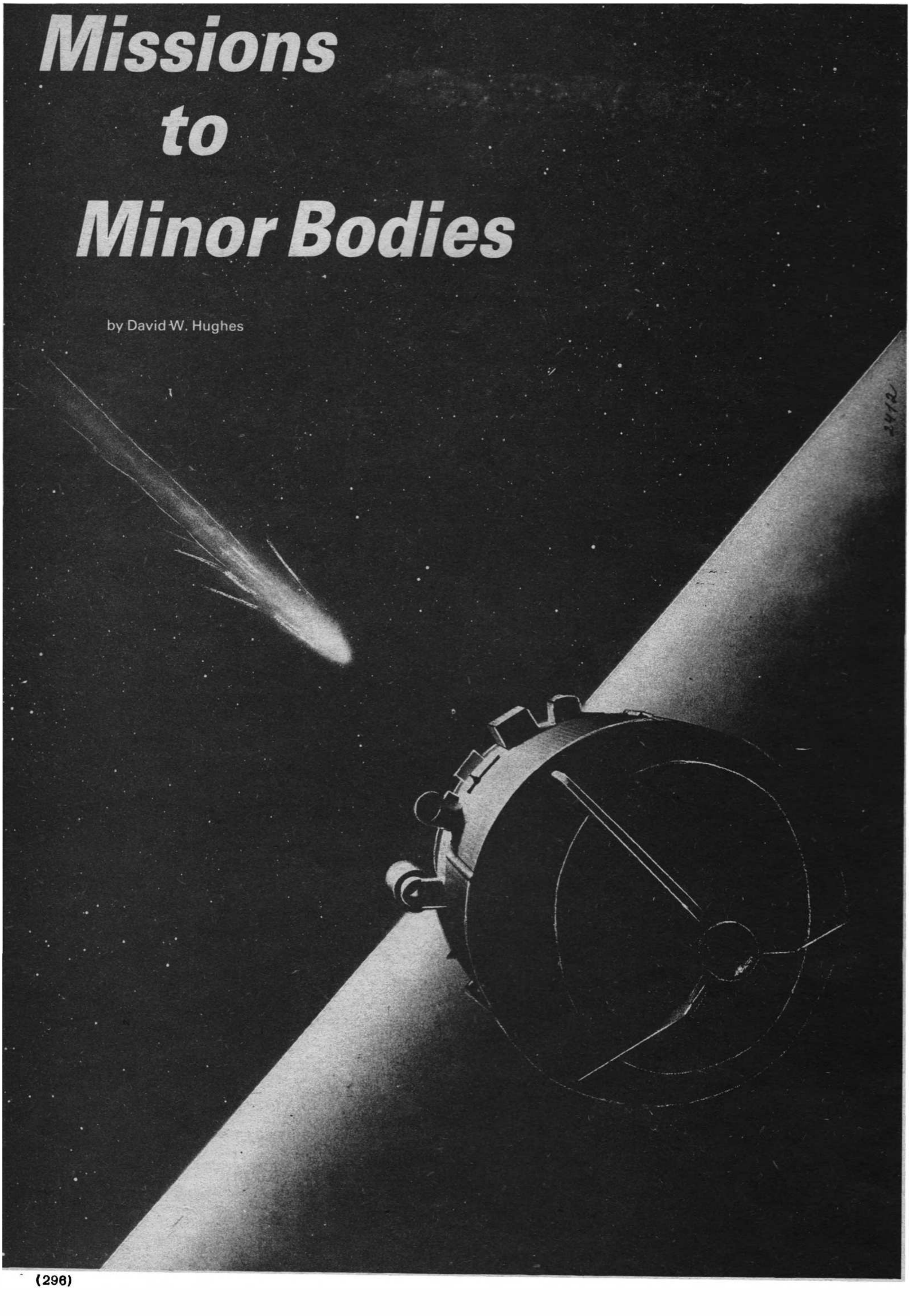
Missions to Minor Bodies

by David W. Hughes



Comets and asteroids are enticing venues for the next big leap forward in the space investigation of the solar system. So far three exploratory missions have occurred. In March 1986 Giotto glimpsed a cometary nucleus from a distance of 605 km. At a stroke this converted our hypothetical musing about the large dirty snowball nucleus into startling reality. In 1976 Viking Orbiter 1 passed within 88 km of Phobos and Viking Orbiter 2 within 28 km of Deimos. This is the nearest we have got to any "asteroids" although, unfortunately, close-ups of the moons of Mars, which *might* be captured asteroids, are not the same thing as images of the real asteriods that have been orbiting for eons in a belt around 2.8 AU from the Sun. Still, we have seen three minor bodies and the images have shown convincingly what fascinating objects they are. But the scientists aren't satisfied. They want more.

Stages of Exploration

Missions to minor bodies can easily be compared with the sequence of missions to the Moon. There are three stages of exploration. In the case of the Moon these can be typified by Luna 3 (October 1959), Surveyor 6 (November 1967) and Apollo 15 (August 1971). The first of these flew past the Moon and relayed back to Earth our first tantalising glimpse of the far side. The second landed softly on the surface, took 30,000 images of the surrounding landscape, used an alpha particle scattering detector to analyse the soil in the vicinity and then lifted off the surface to re-settle some 2.5 m away from the original landing site. Apollo 15 saw David R. Scott and James B. Irwin use a lunar roving vehicle. Three trips were made around the Hadley-Apennine region and the mission returned to Earth with such treasures as "green soil" and the so-called "Genesis rock".

The analogies with the proposed missions to the minor members of the solar system are obvious. First, a few typical bodies must be surveyed. Secondly, we need a rendezvous mission. Thirdly, samples must be brought back to Earth where they can be analysed in detail in our laboratories.

The Survey Stage

Considering the funding restrictions of the major space nations this stage now shows few encouraging signs.

We have a brief snap-shot of one cometary nucleus and we know what Comet Halley looked like on March 14, 1986 some 33 days after its perihelion passage, at a time when it was 133,000,000 km from the Sun.

However, comets are notoriously changable and it is clear that Halley would have presented a different picture if imaged at some other time. Also, rather like humans beings, no two comets are the same. So the use of Halley as the role model is not without problems. Many comets are smaller or larger, less or more active, not middle aged, and in different orbits.

A clear picture of comets can only be built up from a suite of images taken both of different objects and of the same object at different times. Our glimpse of Halley showed that it had a nucleus that was shaped rather like a smooth avocado pear. The major dimensions were 8 x 8 x 16 km, the surface area being 400 km^2 and the volume 550 km^3. Only 40 km^2 of the surface of the nucleus was active at the time, this being a small fraction of the sun-facing side. Small hills and depressions were seen and the colour of the surface (a dull grey), seemed depressingly uniform. The density of the nucleus is estimated to be about 0.2 ± 0.1 gm cm^{-3}, a figure which in itself reveals the inexact nature of our knowledge of the mass. We must remember that Giotto flew past Halley at a speed of 68 km sec^{-1} and that the minimum distance between the comet and the spacecraft was 605 km. So the best image resolution was of the order of 100 m. Our view was non too sharp and only one side of the nucleus was imaged. Other comets will be different; but by how much?

A relatively inexpensive opportunity to investigate one more comet is available. The European Space Agency (ESA) has allocated funds so that the Giotto spacecraft can be reactivated and fully tested when it returns to the proximity of Earth in late 1989 and early 1990. If the major instruments are found to be functional, then, by a combination of an Earth gravitational assist plus the use of onboard fuel reserves, the spacecraft can be targeted to flyby comet P/Grigg-Skjellerup in July 1992.

Asteroids

Phobos and Deimos are our imperfect asteroid models. Both are ellipsoidal in shape, the dimensions of Phobos (whose mean distance from the centre of Mars is 9270 km) are 20 x 23 x 28 km. Deimos (which orbits at 23,400 km) has dimensions of 10 x 12 x 16 km. Both have albedos between five and seven per cent and their reflectance spectra resemble "C-type" asteroids. Phobos has a surface rather like the lunar highlands and sports both a 10 km crater (called Stickney) which has radiating chains of crater-lets, plus an unusual series of 500 m wide grooves that could indicate internal fracturing. Deimos has no grooves and is generally blander, smoother and flatter. It also has a thicker, more soil-like regolith than Phobos.

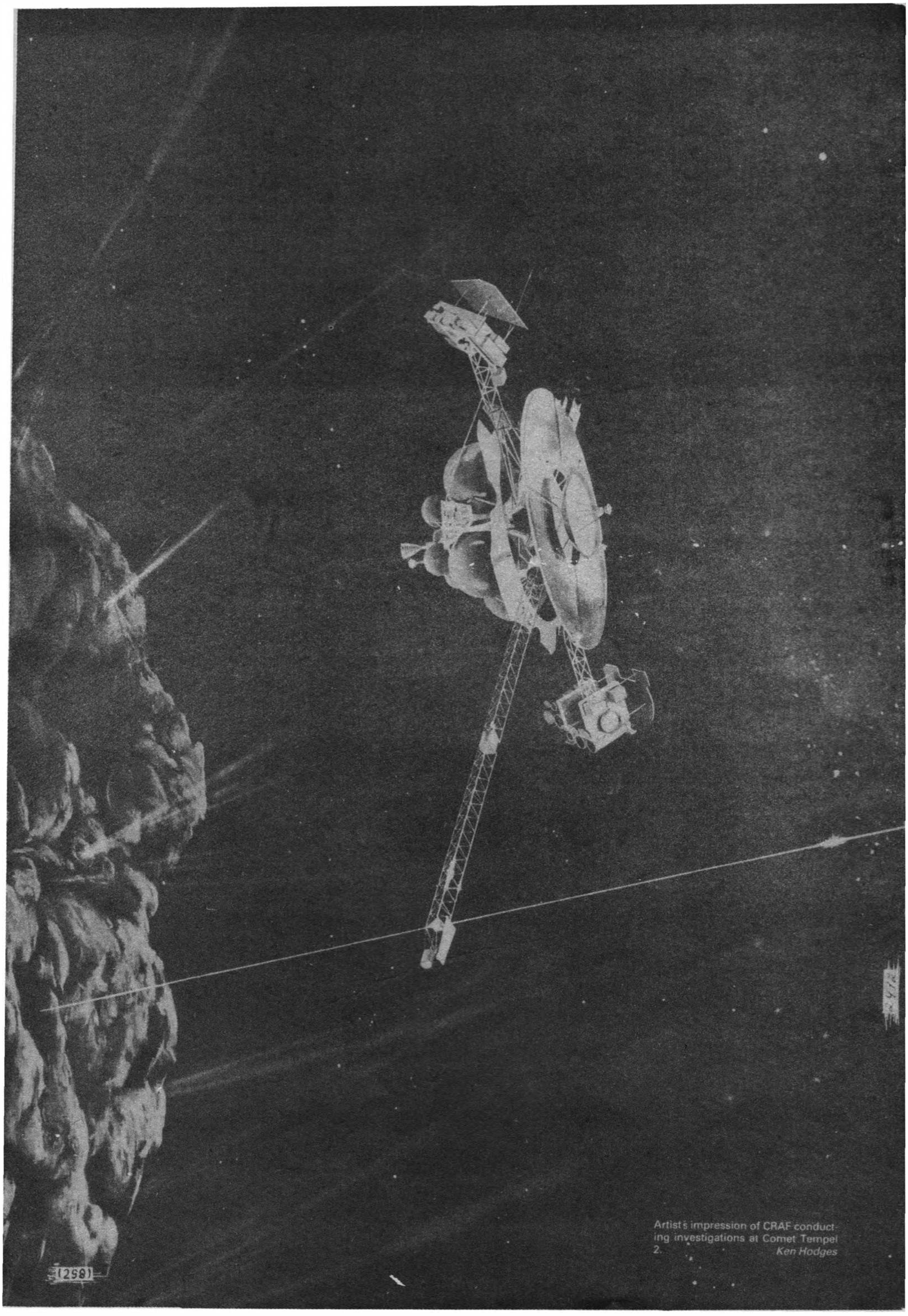
These two "captured asteroids" differ considerably from each other and the real asteroid "zoo" will be even more varied. There are giant asteroids like Ceres (diameter 913 km) and Vesta (diameter 501 km), which are probably pristine remnants of the initial condensation process that led to the formation of the planets. They will have surfaces that are 4,570,000,000 years old and differentiated, radioactive decay having heated the material, which then split into a metal component before sinking to the centre, and a rocky slag that floated to the top to form a mantle.

Only about ten of these original asteroids are left with most of the originals having broken up due to energetic inter-asteroid collisions. In fact, it seems that all the asteroids smaller than about 250 km are irregular fragments. Some of these fragments are rocky, others made of iron, and a minority a mixture of the two. A similar division is also apparent in the meteorites that fall to the surface of Earth.

What is really needed is a determination of the close relationship between meteorites and individual parent asteroids. This would require a flyby mission to the asteroids in which a spacecraft passed closely, and slowly, by a series of dissimilar asteroids as it went on an extended tour of the solar system. Plans for many such missions have been put before ESA and NASA but to date none have progressed beyond the detailed planing phase. A typicaly example was Asterex (Asteroid Exploration Mission), a three year mission in which the spacecraft would have flown by Ceres, Lamber, Mtskhe, 1974 VA and 1930 OK. Typical relative velocities were between 4.3 and 16.7 km sec^{-1} and the model payload included an imaging camera, an infrared spectrometer and radar altimeter.

Cometary Rendezvous

A second and more complex stage in the exploration of the solar system's minor bodies, requires the spacecraft to catch up with the object and then to stay with it for long enough to carry out a detailed survey. In the early 1980's NASA planned a mission that would rendezvous with the periodic comet,



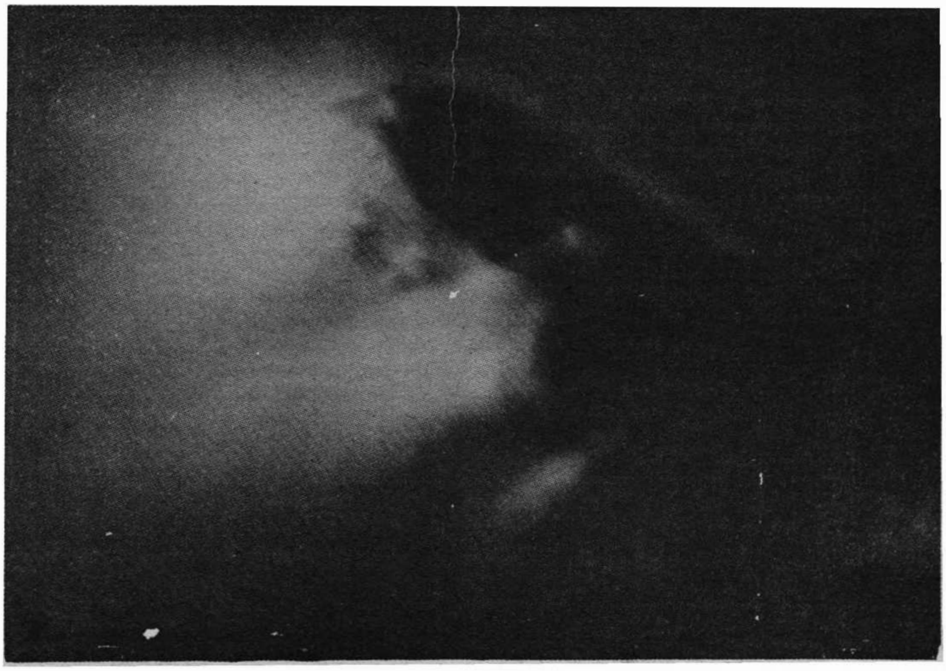
Artist's impression of CRAF conducting investigations at Comet Tempel 2. *Ken Hodges*

Tempel 2, but unfortunately it was not funded. The spacecraft (complete with its solar-electron propulsion system) would have met the comet in July 1988 when it was a distance r = 1.58 AU from the Sun. It would have then stayed with it through perihelion passage (September 1988, r = 1.38 AU) and on until the comet had retreated to a distance of 3 AU in July 1989.

The activity of a typical comet is proportional to $1/r^4$ so the spacecraft would have monitored many changes. Such a comet also loses around 10^{13} to 10^{14} gm of gas and dust at each perihelion passage. The effect of this on delicate space instrumentation is limited by the fact that the gas is expanding very quickly into a near vacuum. However, as a caution, NASA planned to back off from the comet during the period of maximum activity near perihelion passage. The finale of the mission was a soft landing onto the surface of the comet and the payload would have included a camera system, a gas and dust mass spectrometer and a series or ion and electron energy analysers, plus a magnetometer.

The end product would have been the complete maping of the surface of the cometary nucleus and a monitoring of the variations caused by the mass loss. Comets have jets of gas and dust coming from specific active zones and these are switched on and off as the dirty-snowball nucleus rotates and exposes different facets to the solar radiation flux. All this activity would be seen as a function of time.

The surface of a cometary nucleus is expected to be covered with hills, pits and hollows. The minimum resolution of the camera, after the soft landing, would be around one centimetre and the chemical composition of the gas and dust, their spatial densities and the gas to dust mass ratio could easily be measured. What would be even more exciting would be the monitoring of the variations in these properties as a function of distance from the Sun. The mass, density and spin mode of the nucleus could be assessed. Also, the spacecraft could be moved about within, and just outside, the coma of the comet and the data collected used to map out the plasma-sphere, the shock regions and the interaction with the solar wind.



Giotto multicolour camera composite image of the nucleus of Comet Halley. *Max-Planck*

Asteroid Rendezvous

Rendezvous with asteroids would provide detailed maps of their surfaces. Colour variations would give clues as to changes in composition and the physical nature could be revealed by studying the polarisation of the reflected light. The spacecraft could also be made to hover just above the surface and the composition of the rocks and regolith could be guaged by alpha partical reflection spectrometry. The mass and density of the asteroids could be obtained by noting the perturbations that they induced into the orbit of the spacecraft.

Both types of rendezvous mission are limited by the fact that massive instruments have to be carried to the comet or asteroid. Also, the amount of detail that can be relayed back to Earth is restricted by the power available onboard the spacecraft and the bit rate that can be transmitted by the telemetry system.

Rendezvous is superb for producing maps of the surfaces of the minor bodies and for monitoring conditions in their vicinities but when it comes to a *detailed* knowledge of the composition and physical and chemical state of the material we must move to the third stage of exploration.

Sample Return

The Apollo missions showed the way. There is nothing quite like having consideralbe quantities of Moon rock actually in Earth-based laboratories for making new discoveries. The same can be said of asteroids, and even more so of comets.

This third stage type mission is clearly getting much more expensive and complicated than those discussed previously. Not only must the spacecraft go to a comet, slow down when it gets there and orbit the nucleus, it must also survey the surface, pick out some interesting landing sites, touch down, collect the material, take off, come back to Earth and be recovered.

There are two further complications. The material in the dirty snowball nucleus is at a temperature of about −140 degrees centigrade and is protected from the searing heat of the Sun by an insulating, friable, spongey dust layer several centimetres thick. It is clear from the development of cometary comae that the chemistry of the material is very temperature dependent. It is thus essential that a considerable percentage of the returned sample is refrigerated and maintains its initial "cometary" temperature. The physical state of cometary dust will have to be monitored insitu.

The cometary surface is an environment where both the gas pressure and the gravitational field are nearly zero. Even under very small pressures (10^4 dynes cm^{-2} for example) the dust would fragment and be crushed. To examine the crystal structure and composition of the dust it is best to simply collect scoops of the cometary material and then compact it while letting the interstitial snow sublimate as the dust takes up the ambient temperature of the space environment. Ideally, samples should be returned from several sites on the surface of the nucleus and from a series of depths ranging from a few centimetres to a metre or two.

The second main problem with cometary sample return is that we have very little knowledge as to the physical nature of the surface material. At the present time some scientists are designing rock drills, reminiscent of the more difficult aspects of oil prospecting, while others are thinking in terms of spoon-like scoops.

It is very difficult to envisage how a sample return mission can be planned without being preceeded by a rendezvous and soft-landing mission. At the present rate of progress it could be 2015 before we see "freezer boxes" of cometary material in our Earth based laboratories.

David Hughes is senior lecturer in astronomy and physics at the University of Sheffield He has studied the minor bodies of the solar system throughout his research career and was a co-investigator on two of the experiments on the Giotto mission At present he is a vice-president of the Royal Astronomical Society and sits on two of the committees of the British National Space Centre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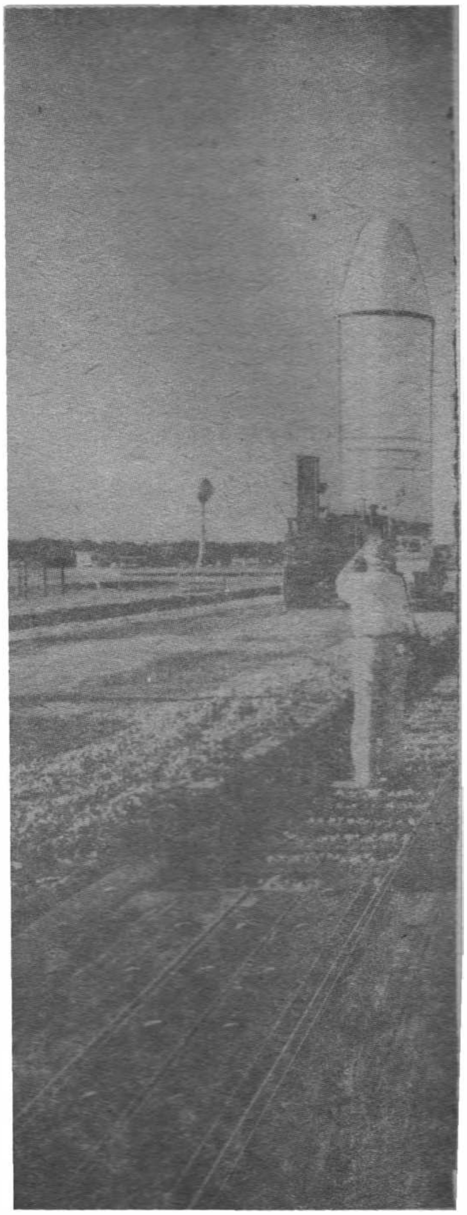
Front Cover: This dramatic artist's impression of the launch of Ariane 4 captures all the excitement surrounding the first mission of Europe's newest rocket. A special report on the important launch opens this action-packed issue of ***Spaceflight*** (see overleaf).

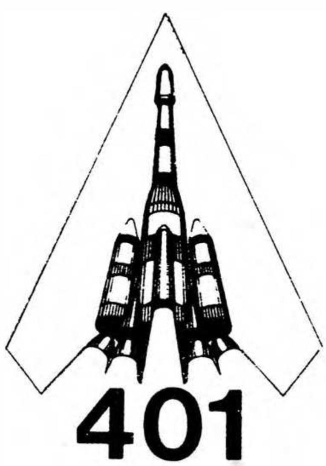


An engineer radios instructions to controllers during the roll-out of Ariane 401 *Arianespace*

The composite payload of three satellites is transferred

First Ariane 4 Launch Success

Report by Clive A. Simpson



June 15, 1988. The new ELA-2 launch pad towering 20 storeys into the sky and Europe's first Ariane 4 pierce the distant horizon as the countdown enters its most crucial phase.

Ariane 4 is a new pinnacle in Europe's proud history of achievement in space technology, yet the contrast between this new commercial satellite launcher now poised for take-off and the primitive surroundings of French Guiana could not be more profound.

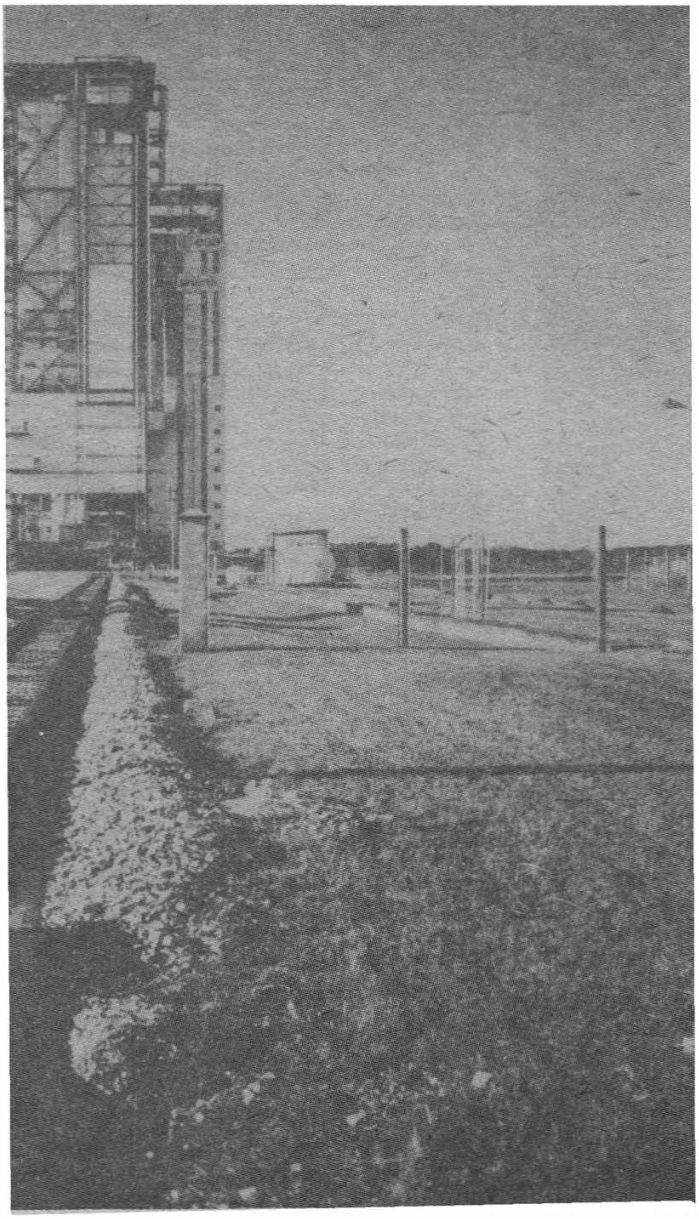
Kourou, sited on a strip of savannah and jungle between the Amazon rain forest and the Atlantic Ocean, has grown into one of the world's most modern space ports.

In the launch control centre two sophisticated computers have now taken complete charge of the final six minutes before the command is given for lift-off. One computer carries out flight configuration of the fluids and propellants and the associated checks. The other executes final preparation of the electrical systems (initiation of flight programme, start-up of servomotors, switch-over from ground power to flight batteries, etc) and corresponding check-out operations.

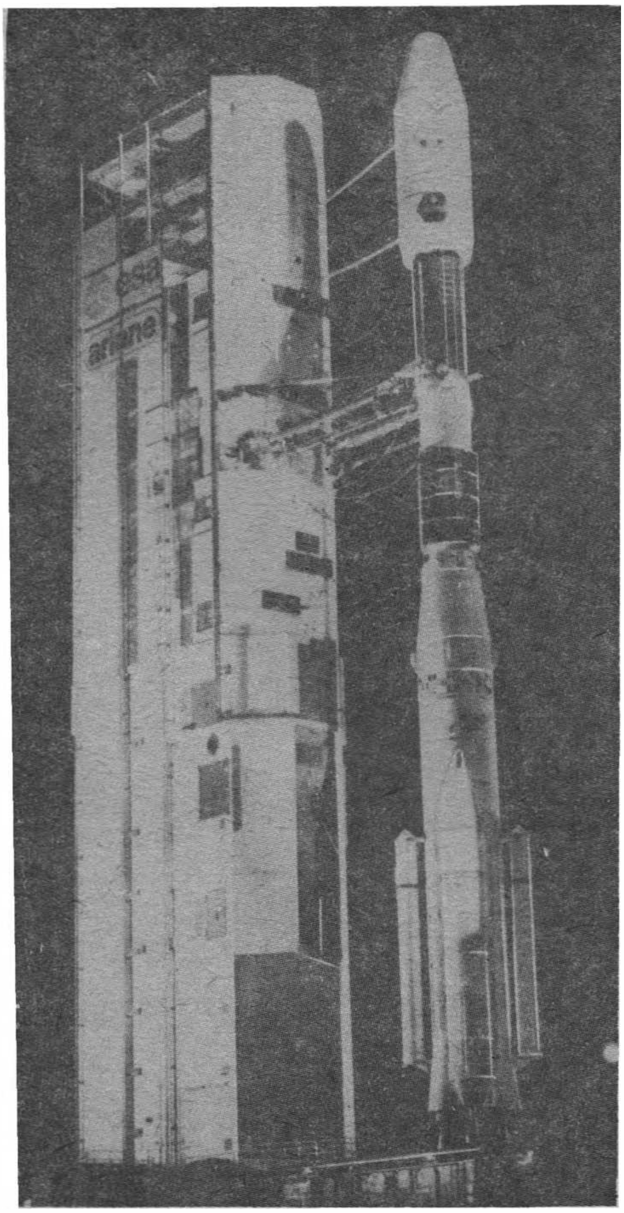
Only a few tens of kilometres away from this miracle of modern technology live Amazon Indians, where time is on an altogether different scale and where distances are measured in terms of paddling time or by the number of bends in a river.

In 1954 Kourou was chosen as a launch site by the French space agency (CNES) because it ideally satisfied two essential requirements: fuel saving and safety.

Kourou, at a latitude of only 5.3 degrees north of the equator makes it possible to send into orbit, at an equal



o the launch pad. *Arianespace*



The first Ariane 4 on ELA 2 after ganty withdrawal. *Arianespace*

cost, a payload 17 per cent heavier than the equivalent launched from Cape Canaveral in Florida. Kourou is nearer the Equator and because the Earth rotates from west to east and the velocity at the surface of the Earth is equal to zero at the poles and increases to a maximum as you get closer to the Equator.

The other important consideration is safety – space centres are usually situated on the Eastern seaboard of a continent or island so that the first stages of a launch vehicle and, in the event of a crisis, the vehicle itself, do not fall on an inhabited area. From Kourou a space vehicle launched in an easterly direction will not encounter land before Africa and, in a northerly direction, before Canada.

However, there are drawbacks, mainly relating to inhospitable aspects of the environment. For instance, the high degree of humidity and the possible corrosion of metal structures by salinity. Also, tiny insects, called builder flies (one of the 40,000 different species in a single hectare of Amazonian jungle), make their nests on the vehicle and secrete a substance which they use as a binding material and which effectively blocks all the air vents. To keep them away air is constantly blown from inside the launcher.

The range extends along a 15 km coastal stretch between Kourou, which used to be a small fishing village, and Sinnamary, a sleepy river crossing.

Various facilities for remote sensing and telemetry are also located in the region – on the Montagnes des Peres where Jesuit missionaries once settled, and on one of the iles du Salut where convicts were sent.

The ELA 2 pad is south of the launch control centre where the countdown is now about to enter the final 60 seconds. Its structure is completely different from ELA 1 where launchers are assembled, integrated and connected to the umbilical tower in the building which is withdrawn prior to launch.

The first of the Ariane 4 series (Ariane 401) was assembled in the new ELA 2 building and then transferred on April 28 to the launch base 950 m away on a trolley that glides along rails.

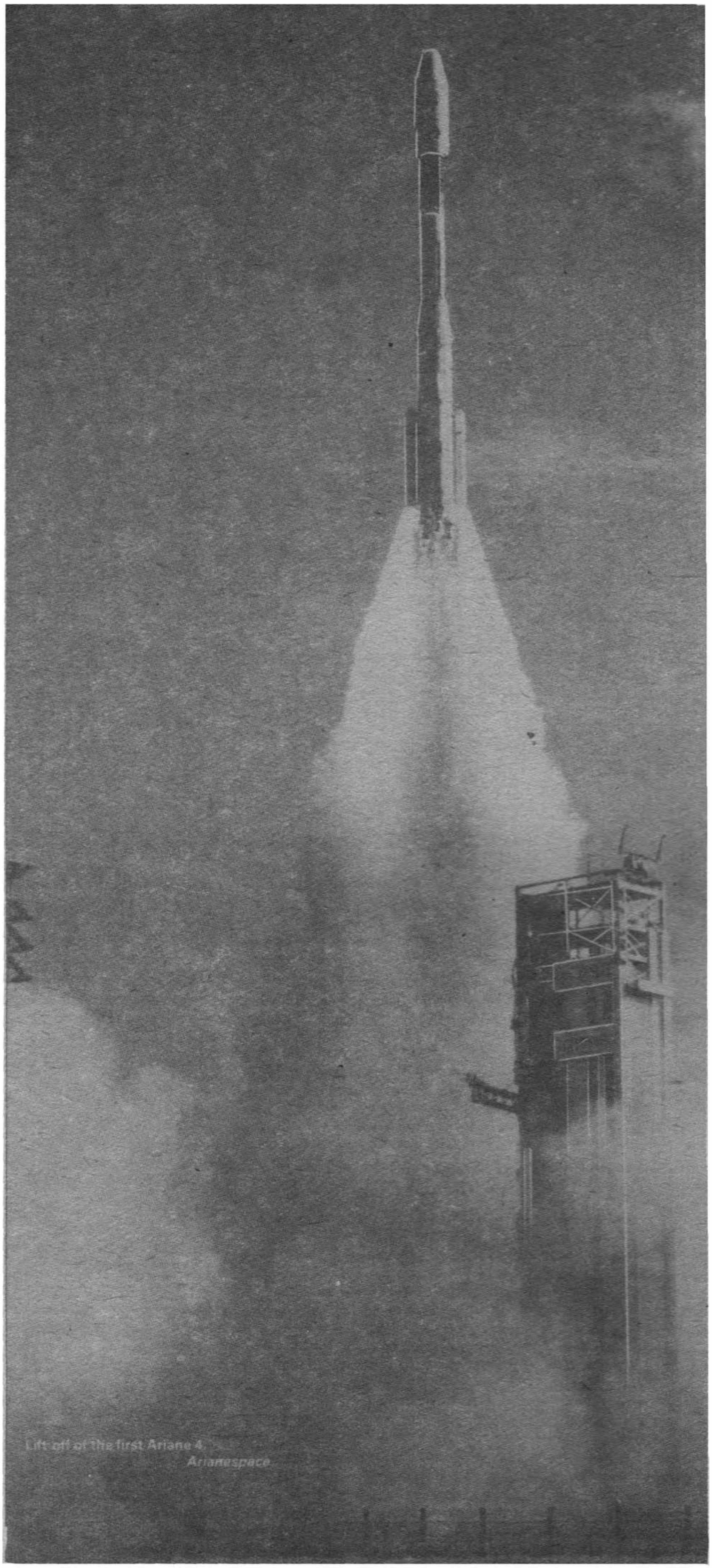
"Cinq, quatre, trois, deux, un..." the countdown is finished. Suddenly there is a mass of flame as the liquid boosters and first stage burst into life. For a fraction of time Ariane 4 remains motionless, straining for release from the launch table jaws.

Then at 08 hours 19 minutes and 01 seconds local time Ariane 4 rises into the blue sky. Spectators in the distant enclosure are already cheering and clapping by the time the thunderous roar of the mighty engines reaches them across the lush savannah. The demonstration flight of Europe's new launcher is underway.

Triple Payload

The first Ariane 4 placed three satellites with a combined mass of 3513 kg in geostationary transfer orbits. These were ESA's European weather satellite Meteosat P-2, the communications satellite Pan American Satellite 1, and the amateur radio satellite AMSAT III C. Parameters provisionally calculated on injection of the third stage were as follows:

perigee : 221 km ($\pm$ 1 km) compared


Lift-off of the first Ariane 4. *Arianespace*

	to a target of 220 km
apogee :	36 359 km (± 100 km) compared to a target of 36 294 km
inclination :	10.01 degrees (± 0.5 degrees) compared to a target of 10 degrees.

The version of Ariane 4 used on this occasion, 44LP, had two liquid and two solid propellant boosters, a configuration which gave opportunity for an in-flight validation of all the new elements on Ariane 4.

The Ariane 4 solid propellant boosters (SPBs) are based on those used for Ariane 3, differing solely by virtue of their longer burn time (42 seconds compared to 30 seconds, requiring the body to be stretched by 1 m) and the inclination of the nozzle (12 degrees as against 14 degrees on Ariane 3).

The SBPs are ignited on lift-off, following checks on the chamber pressure on the first stage engines and liquid propellant boosters (LPBs), at the same time as the jaws holding the vehicle on the launch table are opened.

For safety reasons – to ensure they do not fall back to Earth too close to the launch site – the SPBs are jettisoned using a separation system based on four springs some ten seconds after burn-out, approximately 66 seconds into the flight.

The LPBs are very close in their design and operation to those used on the first and second stages of the Ariane launcher and use the same fuels (UH 25 and N_2O_4) and the same type of Viking engine.

As with the first stage, the LPB tanks are pressurised before the engines are ignited by means of nitrogen from the

Pan American

The PAS 1 communications satellite is the maiden craft of Pan American Satellite, the first private company in the world to own and operate an international satellite outside the Intelsat consortium. It is also the first private satellite ever to provide an affordable, state-of-the-art communications service between Latin America, the United States and Europe.

PAS 1, which will maintain a geostationary orbital position of 45 degrees West Longitude, is a modified RCA Astro Series 3000 communications satellite designed to operate in both the C- and Ku-bands. It has 24 transponders, accessible via small and inexpensive antennas that may be located on premises virtually anywhere. As a result, the PAS 1 can make high-quality satellite communications available to areas that were previously too remote or too densely populated to be practically served.

PAS 1 will accommodate virtually any type of communication, including voice, data, telex, facsimile, teletext, broadcast and video. Its advanced transmission capabilities are designed to provide international and domestic

ground facilities, and in flight by means of hot gases produced by the gas generator of the Viking engine.

The LPBs are attached at the rear of the main body of the Ariane 4 launcher by a swivel joint fixed to the 1PB thrust frame and, at the front, by rods attached both to the LPB forward skirt and to the first stage L220 inter-tank skirt.

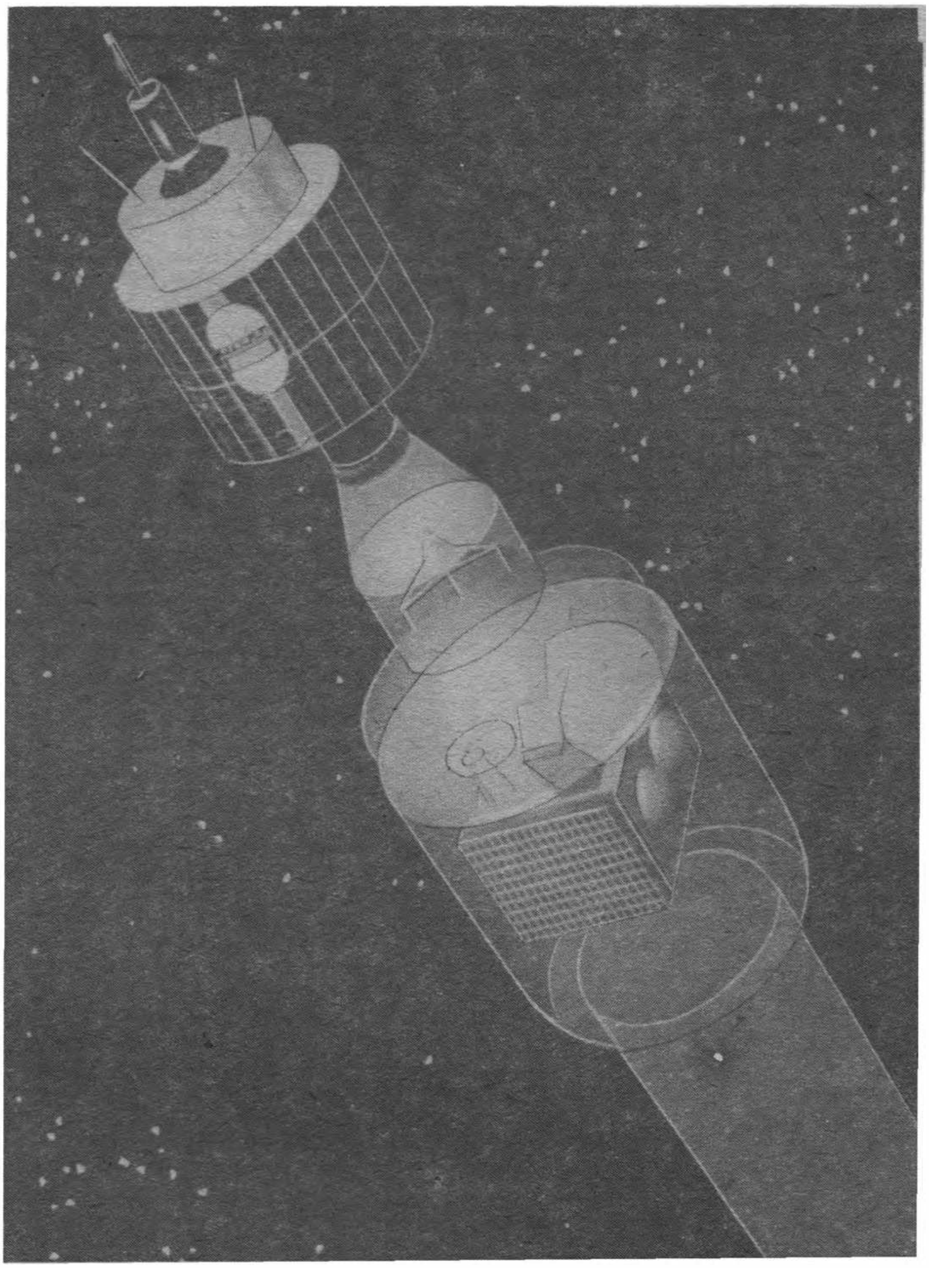
The LPBs are ignited at the same time as the four first stage engines, around three seconds before lift-off; opening of the jaws holding the launcher on the launch table is contingent upòn checkout of proper operation of the LPBs and the first stage engines.

Power and Flexibility

Ariane 4 is able to place payloads of 1900 to 4200 kg in geostationary transfer orbit and is thus almost twice as powerful as Ariane 3. With the flexibility afforded by six versions of the launcher and a multiple launch system, performance and volume can be tailored exactly to payload requirements.

The main features distinguishing this launcher from its predecessor, Ariane 3, are:

- A first stage with a 50 per cent longer burn-time and a propellant capacity increased from 148 to 234 tonnes.
- New solid and liquid propellant boosters that can be used in various permutations to give six different launcher configurations.
- A new vehicle equipment bay comprising up-rated electronics, a digital flight-control system and, for



Artist's impression of the triple payload, Meteosat P2 is on top, AMSAT IIIC centre and PAS 1 below. *ESA*

Satellite 1

communications throughout several major coverage areas:

- C-band coverage for US/Latin America communications.
- Ku-band coverage for US/Europe communications.
- Combination C- and Ku-band coverage for US/Latin America/ Europe communications via Pan American Satellite's Miami International Gateway.
- C-band spot beam coverage to individual countries in the Caribbean and northern, central and southern Latin America.

Once operational, the PAS 1 will help public and private industries to economically expand existing communications lines into remote areas and establish private information networks between geographically distant offices. It will also provide the means for creating national satellite networks to Latin American countries that might otherwise have been unable to afford them. And for television and cable networks, the PAS 1 can be used to transmit and distribute live or taped programming internationally.

Weather Watch

Meteosat P2 is the third satellite to be launched under ESA's pre-operational Meteosat programme following Meteosats F1 launched in 1977 and F2 in 1981. The latter is still providing images of the Earth every half-hour from its position in geostationary orbit at zero degrees longitude.

The spacecraft is made up of a high-resolution radiometer and the data-dissemination system. Meteosat P2 also carries the LASSO (Laser Synchronisation from Stationary Orbit) experiment, which will be used for experimental synchronisation of atomic clocks over Europe and, eventually on both sides of the Atlantic.

The pre-operational Meteosat programme, Europe's contribution to the observation programme set up by the World Weather Watch, is funded by eight of the ESA member states (Belgium, Denmark, France, Germany, Italy, Sweden, Switzerland and the United Kingdom).

Meteosat P2 has been built as a qualification model for the pre-operational programme and although a number of improvements have been made, P2 cannot really be seen as a normal flight model; it will, however, ensure continuity until the first operational Meteosat, MOP 1, is put into orbit (planned for this autumn). Meteosat P2 is stationed in geostationary orbit at zero degrees longitude.

The operational Meteosat programme, under which three further satellites have been built and will be launched, follows on from the pre-operational programme; it will provide service to the meteorological community until the mid-1990's. Since 1986 the running of the satellites, and the procurement and the launching of the MOP series, has been carried out by ESA on behalf of Eumetsat, which represents the weather services of 16 European countries.

New Ham Radio Satellite

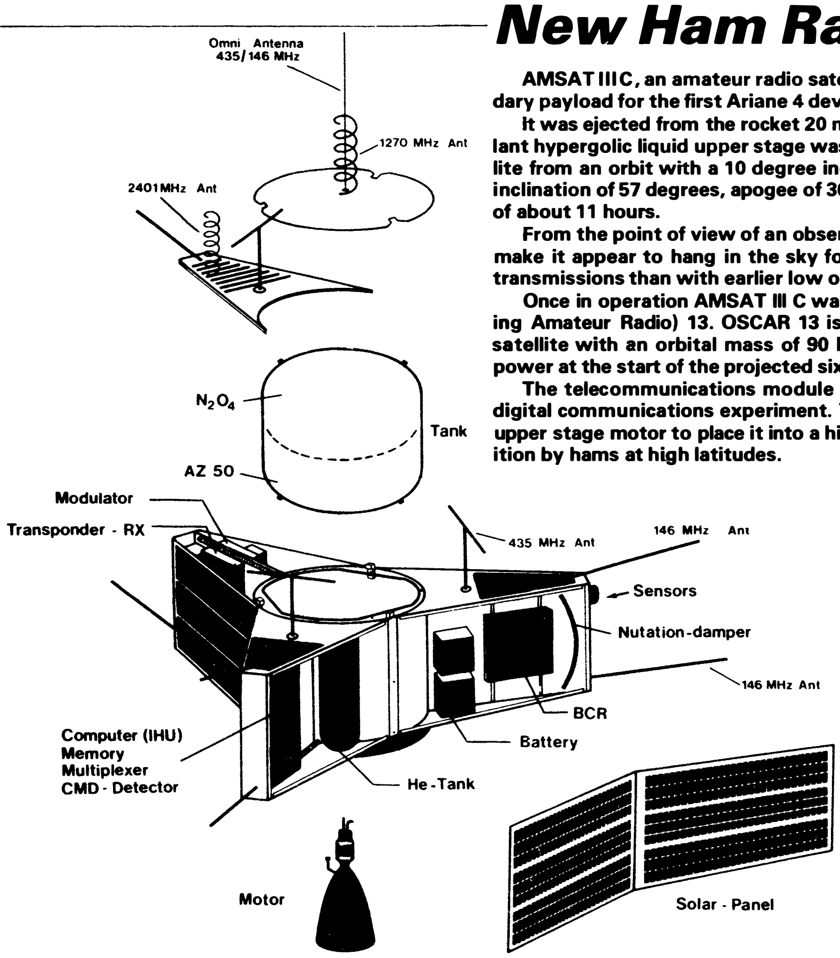
AMSAT III C, an amateur radio satellite, was launched on June 15 as a secondary payload for the first Ariane 4 development flight, ***writes Philip Chien.***

It was ejected from the rocket 20 minutes after launch and its own bi-propellant hypergolic liquid upper stage was fired three days later, changing the satellite from an orbit with a 10 degree inclination into an operational orbit with an inclination of 57 degrees, apogee of 36,000 km, perigee of 1,500 km, and a period of about 11 hours.

From the point of view of an observer on the ground the satellite's orbit will make it appear to hang in the sky for several hours at a time enabling longer transmissions than with earlier low orbit AMSATs.

Once in operation AMSAT III C was renamed OSCAR (Orbital Satellite Carrying Amateur Radio) 13. OSCAR 13 is a three side, star-shaped, spin-stabilised satellite with an orbital mass of 90 kg and solar cells to produce 40 Watts of power at the start of the projected six year life-time.

The telecommunications module includes three sets of transponders and a digital communications experiment. This OSCAR 13 is the first AMSAT with an upper stage motor to place it into a high inclination orbit, a necessity for acquisition by hams at high latitudes.



AMSAT III C was built by West German ham radio operators, primarily from spare parts and donated efforts. Hams in the United States, Japan and Hungary also contributed to the construction.

The AMSAT programme is unique in its structure and operation. Unlike other aerospace projects the labour and design time is donated by amateur radio operators, with the space parts which make up the satellite donated by aerospace companies and government agencies. With low construction costs and launch services donated by launch agencies, AMSAT is the world's only non-profit satellite programme. Users are not charged for the use of AMSATs. They are encouraged to help donate funds to operate and build future OSCARs.

the first time on a launcher, a gyrolaser inertial platform to back up the main platform.

- A fairing with a larger diameter (4 m), available in various heights.
- A new bearing structure for dual launches (the SPELDA), providing much larger useful space to accommodate payloads.

The Ariane 4 development programme, in which 11 European countries (Belgium, Denmark, France, the Federal Republic of Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland and the United Kingdom) have taken part, was decided upon in 1982 by the European Space Agency, which appointed the Centre National d'Etudes Spatiales (CNES) as prime contractor for the launcher project.

Over 50 European firms are involved in this programme under an industrial organisation built around eight level-1 contractors: Aerospatiale (the industrial architect, also responsible for the first and third stages), MBB-ERNO (second stage and liquid boosters), SEP (propulsive systems for all three stages), SNIA-BPD (solid boosters), Air Liquide (third-stage tanks), MATRA (vehicle equipment bay), Contraves (fairings), and British Aerospace (SPELDA). Launch operations will be carried out by Arianespace.

The success of this flight clears the way for commercial use of Ariane 4, which is going to be Europe's "space workhorse" for the next ten years. In an increasingly competitive climate, this launcher will enable Europe to consolidate its share – roughly 50 per cent – of the world launch services market.

Arianespace, the commerical company formed to operate Ariane, has already ordered 20 Ariane 4s to launch the 42 satellites making up its current order book, and is in the process of ordering a further series of 50.

Mr. Fredrick d'Allest, Director General of CNES and Chairman of Arianespace, described the first Ariane 4 launch as "a key milestone" in the development of the European space effort.

"Among all those throughout Europe who have contributed to this success, I want to pay a special tribute to the CNES Launch Vehicle Directorate which conceived the Ariane family and led the successful development of Ariane 4.

"Arianespace now has a powerful, flexible vehicle to meet the growing worldwide competition in commercial launch services and to consolidate its leading position in the market," he said.

UK-built Payload Structure

SPELDA (Structure Porteuse Externe pour Lancement Double Ariane), designed and built by British Aerospace, is an external supporting payload bay structure which will enable Ariane 4 to launch independently two or more spacecraft during the same mission.

The main structure, a large cylinder 3.97 m in diameter below a truncated conical section, is mounted above the Vehicle Equipment Bay.

The upper satellite is carried on a mounting ring fitted to the top of the conical section and the second satellite is enclosed within the cylindrical portion.

Early in the flight, Ariane's nose fairing is jettisoned to allow the upper satellite to be released into orbit. After launch of the first satellite, a pyrotechnic charge separates the upper and lower sections of SPELDA before the upper section is propelled away by a pre-compressed spring system leaving the second satellite free for release into transfer orbit.

For triple payload launches, SPELDA is used in conjunction with SYLDA (Systeme de Lancement Double Ariane) or, in the case of the maiden flight of Ariane 4, an APEX adaptor (Ariane Passenger Experiments).

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

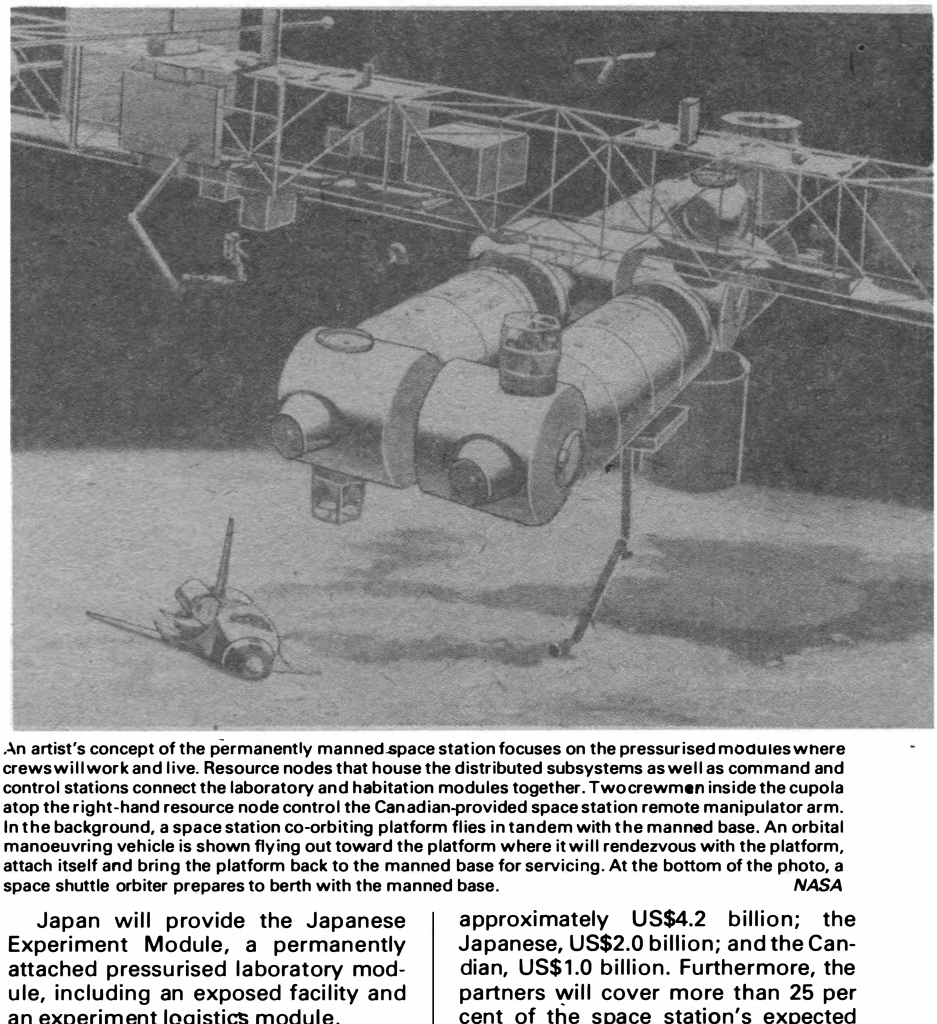
Partners End Complex Talks

Negotiations between the United States, Canada, Europe and Japan on the framework for cooperation in the international space station programme were completed in early June.

It marked the end of more than two years of complex negotiations on the design, development, operation and use of the permanently manned space station. Spanning decades, the space station will be the largest international scientific and technological venture ever undertaken.

Cooperation in the space station programme dates back to President Ronald Reagan's January 1984 invitation to friends and allies of the United States to join in the development of the versatile facility and to share in the benefits of its use. Subsequently, the President has addressed space station cooperation at four intervening economic summits and at numerous bilateral meetings with the partners' heads of government.

The US Congress also endorsed space station cooperation. The NASA Authorisation Act of 1988 directs NASA to: "promote international cooperation in the space station programme by undertaking the development, construction, and operation of the station in conjunction with... the governments of Europe, Japan and Canada."



An artist's concept of the permanently manned space station focuses on the pressurised modules where crews will work and live. Resource nodes that house the distributed subsystems as well as command and control stations connect the laboratory and habitation modules together. Two crewmen inside the cupola atop the right-hand resource node control the Canadian-provided space station remote manipulator arm. In the background, a space station co-orbiting platform flies in tandem with the manned base. An orbital manoeuvring vehicle is shown flying out toward the platform where it will rendezvous with the platform, attach itself and bring the platform back to the manned base for servicing. At the bottom of the photo, a space shuttle orbiter prepares to berth with the manned base. *NASA*

The international space station complex includes a manned base which will be operated by an international crew in the mid 1990's.

The entire complex, with its diverse capabilities, will be a focal point for space operations into the next century. As an orbiting research laboratory, the station will increase scientific knowledge, stimulate the development of new technology and enable commercial research. In the future, the space station is also required as the stepping-stone for the eventual expansion of human presence into the solar system.

The US will provide the overall space station framework, operating subsystems including life support and 75 kilowatts of power, laboratory and habitat modules and an unmanned free-flying platform that will be placed in polar orbit for Earth observation.

Canada will provide a Mobile Servicing System which will be used in conjunction with the assembly, maintenance and servicing of space station elements.

Japan will provide the Japanese Experiment Module, a permanently attached pressurised laboratory module, including an exposed facility and an experiment logistics module.

The European Space Agency (ESA) will provide a pressurised laboratory module, also to be permanently attached to the manned base; an unmanned free-flying polar platform to work together with the US polar platform; and a man-tended free flyer to be serviced at the manned base.

NASA has been working since 1985 with its Canadian, European and Japanese partners in the defintion and preliminary design phase of the project. Such cooperation has resulted in programme-level agreement on the above hardware.

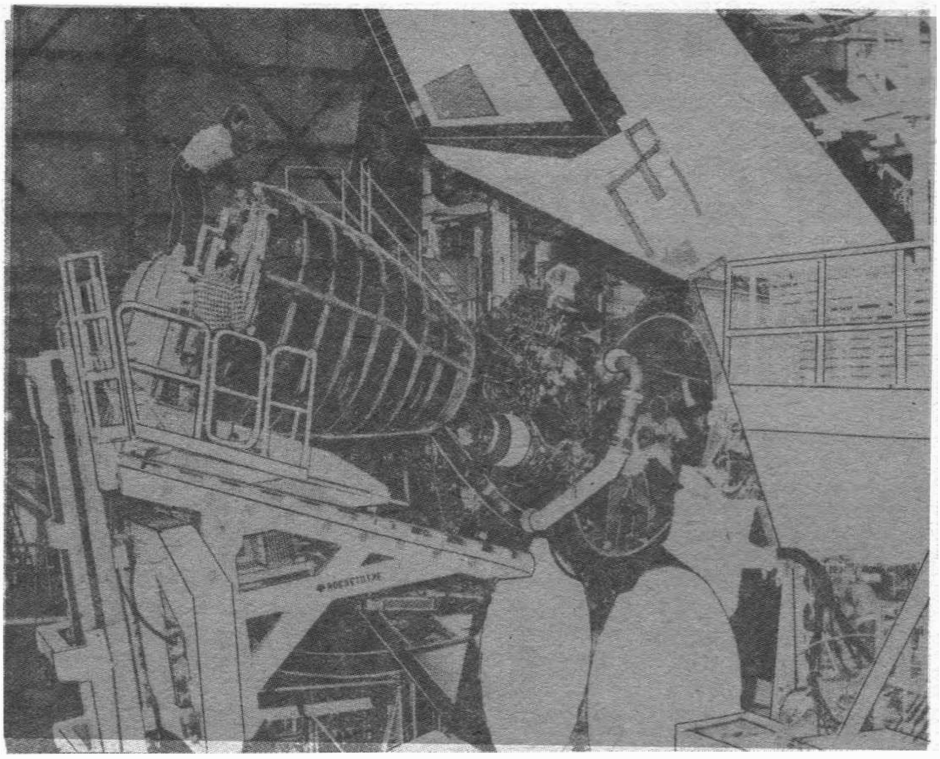
The US anticipates spending approximately US$16 billion to develop space station hardware and the total foreign commitment is in excess of US$7 billion.

The European hardware development programme will amount to approximately US$4.2 billion; the Japanese, US$2.0 billion; and the Candian, US$1.0 billion. Furthermore, the partners will cover more than 25 per cent of the space station's expected annual operating costs throughout its 20-30 year life.

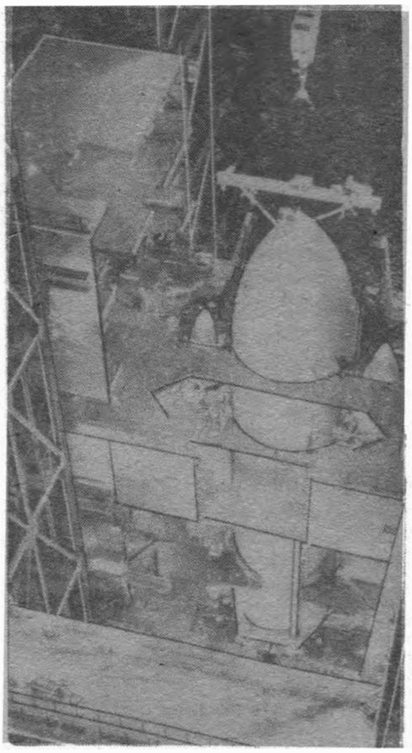
The documents on which negotiations have been completed are a multilateral intergovernmental agreement (IGA) and three bilateral memoranda of understanding (MOUs). The IGA contains the broad principles and the government-level commitments for the cooperative space station programme. The three separate MOU's, which are between NASA and its counterparts, provide the technical and programmatic details for the implementation of the programme.

Negotiators from all four partners have submitted the IGA and MOU texts to their respective governments for consideration in accordance with their internal procedures and signature of the agreements is expected later this summer.

INTERNATIONAL SPACE REPORT



Engineers guide a 7,000 pound engine to the number one position in Discovery's aft compartment. *NASA*



The external tank is lowered beside the stacked solid rocket boosters, June 9. *NASA*

Shuttle Mission Coverage

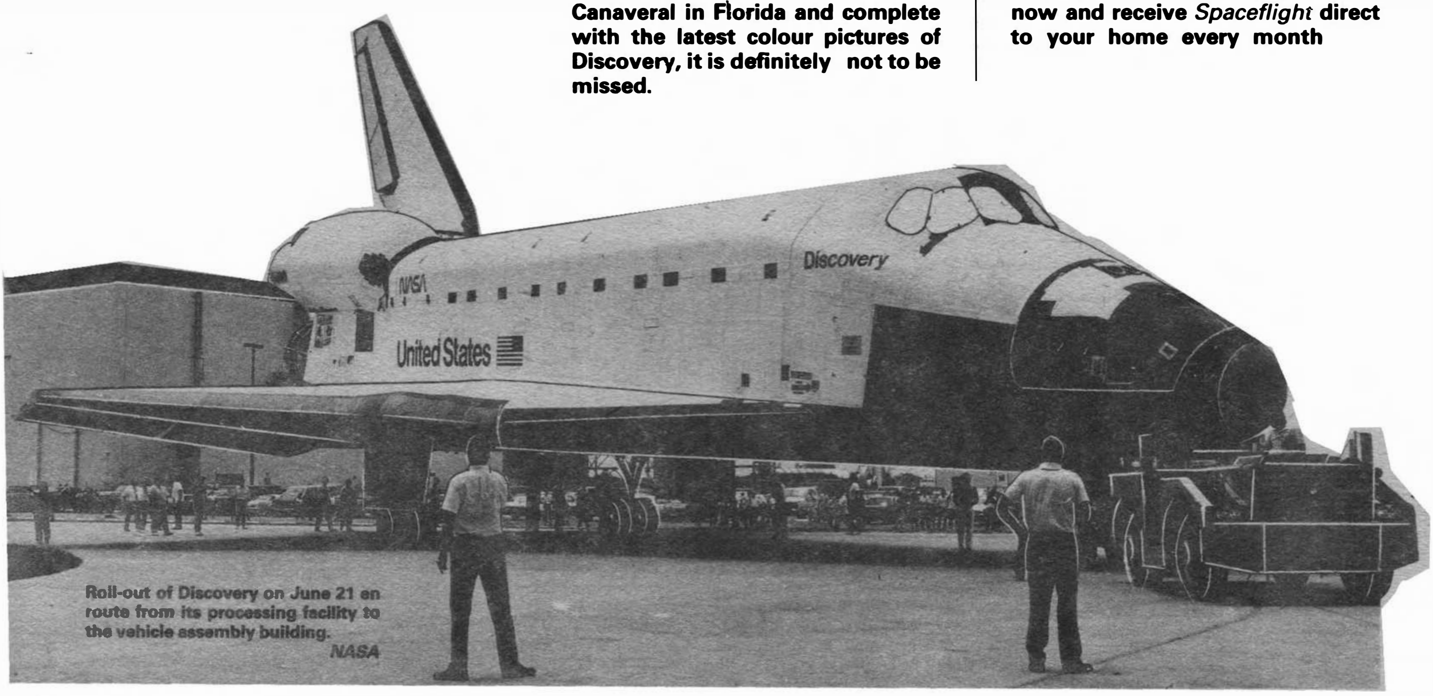
Spaceflight magazine will be providing unrivalled coverage of the up-coming return to flight of the US Space Shuttle on STS-26.

Next month (September) _Spaceflight_ will publish a special return to flight feature bringing you right up-to-date with all that has been going on behind the scenes.

Compiled by Roelof L. Schuiling and Philip Chien direct from Cape Canaveral in Florida and complete with the latest colour pictures of Discovery, it is definitely not to be missed.

The long-awaited launch itself is currently scheduled for the first half of next month (September) and the _Spaceflight_ team in the States will be strengthened by staff from our London office to cover the launch and mission in detail, providing extensive coverage for subsequent issues of _Spaceflight_.

Ensure you don't miss out. Join the British Interplanetary Society now and receive _Spaceflight_ direct to your home every month



Roll-out of Discovery on June 21 en route from its processing facility to the vehicle assembly building. *NASA*

New Space Agencies

Two new European governmental agencies for space activities are likely to come into being during this summer, *writes Theo Pirard.*

In Italy, the establishment of ASI (Italian Space Agency) has been approved by the Senate and awaits final approval. ASI will be the governmental agency to manage the increasing space effort of Italy.

According to Antonio Ruberti of the Italian Ministry for Scientific and Technological Research (MRST), who participated to the recent International Symposium of Europe in Space at Strasbourg, the Italian space budget has grown by 450 per cent during the last five years. This budget will reach a level of 800 billion Italian lires (some $700 million) to support the various national programmes (Italsat, IRIS with Lageos, Tethered Satellite System, SAX spacecraft and microgravity activities) and the Italian contribution to ESA programmes (mainly Columbus, Ariane 5 and Hermes, Data Relay Satellite, technological communications satellites, Fucino control centre).

In Germany, the establishment of DARA (Deutsche Agentur für Raumfahrt) is under discussion by the federal authorities. Its office will be located near Bonn and the final decision officialising DARA as the main federal entity for space activities in Germany should be taken before August.

Studies of Sänger the hypersonic space transportation systems are continuing within a five year National Hypersonic Technology Programme which started early this year. This programme will define and prepare the long-lead technologies required for the development of such an advanced European space transportation system. MBB and Dornier are involved in the conceptual definition. The German decision for this National Hypersonic Technology Programme was triggered by the British proposal for a single-stage horizontal take-off vehicle, Hotol, as well as by the American decision to go ahead with the National Aerospaceplane.

Marconi Win French Contract

UK firm Marconi Space Systems has been awarded a multi-million pound contract by Alcatel Espace of France to design, develop and manufacture communications payload equipment for the French Telecom 2/Syracuse 2 joint civil/military satellites scheduled for launch from 1991 onwards.

The equipment includes command, telemetry and ranging systems and consists of advanced transmitters and receivers operating at 7 and 8 GHz. The contract is for the supply of three sets of flight standard hardware together with development and engineering models.

Advanced SRM for Space Shuttle

Aerojet and Lockheed have teamed up in the bid to win the contract for NASA's Advanced Solid Rocket Motor programme, aimed at developing a new solid rocket booster to replace the motor currently in use on the space shuttle.

Aerojet will design, develop and produce the rocket while Lockheed will conduct systems engineering and integration.

"We're forming this team because we are determined to win this competition and produce the safest, most reliable booster for the space shuttle . The Advanced Solid Rocket Motor is one of the most important future projects in our nation's manned space programme," said Chuck Levinsky, Aerojet Vice-President of the Solid Rocket programme.

Pioneer 10's Incredible Journey

Pioneer 10, the first spacecraft to leave the solar system, is now just over four billion miles from Earth – the most distant human-made object in existence.

The spacecraft continues to make discoveries about the edge of the Sun's atmosphere as it seeks the boundary between the solar atmosphere and the true interstellar gas. It also continues to search for very long wavelength (billions of miles) gravity waves, and for data on a tenth planet.

On June 13, 1988, Pioneer 10 was 4,175,500,000 miles from the Sun, almost 45 times the distance from the Earth to the Sun. Radio signals, moving at the speed of light, now take over 12 hours and 26 minutes to travel from Earth to spacecraft and back, the longest time of any radio communication in history.

Pioneer 10, launched in 1972, continues to operate extremely well as it collects and transmits data back to Earth. Its primary mission, originally scheduled for 21 months, was to assess the feasibility of passage through the Asteroid Belt and provide the first close-up examination of Jupiter and its moons.

Pioneer 10 accomplished all of its original goals by December 1973 and at that point the mission was indefinitely extended. Scientists reprogrammed the probe to explore the Sun's atmosphere and to look for a tenth planet and gravity waves in the far outer solar system and beyond.

Perhaps the most important finding about the outer solar system concerns the heliosphere, the Sun's atmosphere. Pioneer 10 continues to measure the "solar wind", the million-mile-per-hour flow of charged atomic particles boiling off the Sun's surface.

Scientists had predicted that the solar wind would not extend beyond Jupiter's orbit, but their estimates were proved wrong. The probe is now six times that distance, and has not yet reached the boundary of the solar atmosphere, and the Sun's direct influence continues to be strong. A number of scientists believe that this boundary may be as far away as 9.3 billion miles, almost five times the distance from Pluto to the Sun.

Several scientists, including Dr. James Van Allen, Pioneer Principle Investigator and discoverer of the Earth's radiation belts, and Dr. Darrell Judge, University of Southern California, also a Pioneer investigator, suggest that the heliosphere varies in size with solar activity and is nearly spherical in shape. Because of this, they think Pioneer 10 may break through the boundary of the solar atmosphere and pass into interstellar space sometime in the next three years. There the spacecraft could directly measure the interstellar gas. Data on this space between the stars is impossible to obtain direct from Earth.

Recent improvements in NASA ground stations are expected to allow communications with Pioneer 10 to continue until the range approaches six billion miles, more than twice the pre-launch estimates and project manager Richard O. Fimmel expects that NASA will be able to track Pioneer 10 until the craft's power source limits communications toward the end of the 1990's.

Atmosphere Observed on Pluto

The first direct observation of an atmosphere on Pluto has been made by Massacchusetts Institute of Technology (MIT) astronomers flying aboard NASA Ames Research Center's Kuiper Airborne Observatory.

A team of astronomers from MIT including Edward Dunham, James Elliot, Amanda Bosh, Steve Slivan and Leslie Young made the observation on June 9 during a temporary disappearance, or occultation, of a star behind Pluto.

Pluto is the ninth planet from the Sun, more than 2.5 billion miles from Earth and smaller than the Moon. The planet's discovery in 1930 by Tombaugh was based on mathematical predictions of Lowell who observed unexplained motions in Uranus' and Neptune's orbits.

Charon, its only satellite, measures at least half the diameter of Pluto and was first observed in 1978 by James Christy. Pluto is the only planet in the solar system with a moon so near its own size.

The new observations were carried out by the Ames Kuiper Airborne Observatory project team, headed by Carl Gillespie. They were made at 41,000 feet altitude, approximately 500 miles south of Pago Pago, American Smoa, over the Southern Pacific Ocean.

Information about the temperature, pressure and extent of the atmosphere will be derived from analysis of the occultation data. Principal Investigator Dr. James Elliot, of MIT's Earth, Atmospheric and Planetary Sciences Department, and his associates observed Pluto's atmosphere using a solid state video camera attached to the Kuiper's 36 inch telescope.

Elliot's team observed the occulation of a faint twelfth magnitude star by Pluto to study the possible atmosphere by recording changes in the light intensity of the star as it appeared to pass near and then behind the planet. The visible light signal from the star gradually declined as it approached Pluto's disk. Using the same technique, Elliot discovered the rings of Uranus aboard the Kuiper in 1977, while observing a Uranus stellar occultation with the same telescope.

The Pluto occultation was visible only in the Southern Pacific Ocean and the planet's circular "shadow" fell across the Earth in a path 1200 nautical miles wide. The Kuiper's flight through Pluto's shadow may allow a more precise measurement of the planet's diameter to be made when combined with ground-based observational data. Observations of the occultation were also made by Robert Millis of Lowell Observatory in Flagstaff, Arizona, from a ground site in north eastern Australia.

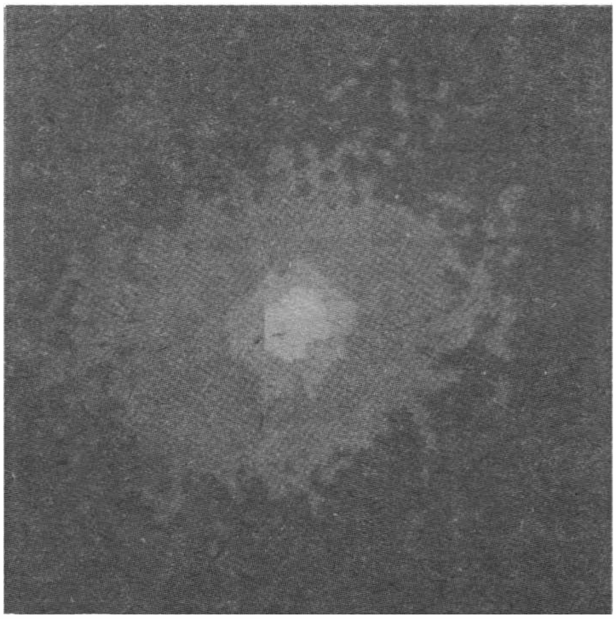
The airborne observations lasted about 1.5 minutes, occurring shortly after midnight on June 9.

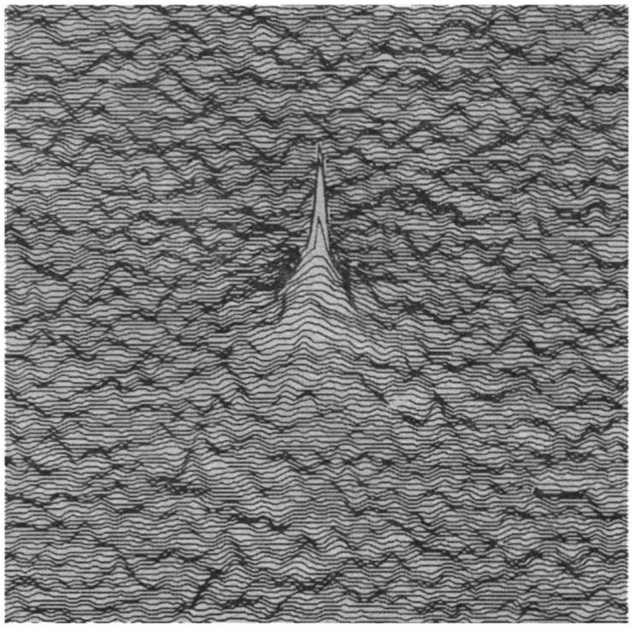
Skynet Launch in 12 Months

The British Ministry of Defence Satellite, Skynet IV, originally scheduled for a shuttle launch accompanied by the country's first astronaut, is to be placed in orbit by a Martin Marietta Titan rocket in August 1989, according to the latest manifest for US expendable boosters.

Skynet, a military communications satellite, will share the launch with a Japanese communications satellite, JCSat.

The manifest includes the British Satellite Broadcasting's BSBR-1 television satellite which is scheduled to be launched by a Delta rocket, also next August.





Comet Halley at 1250 million kilometres

New View of Distant Comet Halley

This picture of Comet Halley was obtained with the Danish 1.5 m telescope at the European Southern Observatory (ESO), La Silla, Chile, during April and May 1988. Halley was observed over 18 nights and a highly sensitive CCD-camera was used to obtain more than 60 images of the comet. In order to detect the faint light from the moving comet, the telescope was set to follow the comet's motion and fortunately, the observations benefitted from very good atmospheric conditions throughout this period.

Extensive image processing was carried out with the ESO IHAP system including "removal" of stars and galaxies in all frames. By putting together about 50 exposures, with a total exposure time of 11 hours 35 minutes, it has been possible to present a picture of Comet Halley as it appears at a distance of 1250 million kilometres from the Sun (almost as far away as the planet Saturn). No picture with so much detail has ever been obtained of any comet so far from the Sun.

The *nucleus* (which is too small to be resolved at this distance) is clearly seen as a small, bright point. The visual magnitude was determined as 23.1 with variations from night to night by a factor of two, reflecting the rotation of the avocado-shaped nucleus, which is located off-centre in a relatively bright, asymmetric region, called the *inner coma*; it measures about 20 arcseconds across, corresponding to 120,000 kilometres. Further out, a larger, *outer coma* of elliptical shape can be distinguished; it measures at least 45 arcseconds (300,000 kilometres) across and is possibly significantly larger. The faintest contour shown is about mag 27 per square arcsecond, or 100 times fainter than the light from the night sky. Summing all of the light, the comet's total magnitude is found to be around 17. The picture at right is a three dimensional representation, illustrating the relative brightness of the nucleus as compared to the coma.

From the shape and density of the inner coma, it would appear that dust is still being released from the nucleus, even at this large distance. By the action of the solar wind, it is pushed away from the nucleus and slowly dissipates into the surrounding interplanetary space. The presence of such a large and faint, outer coma around a comet at this distance has not been detected before; this was only possible because of the very long exposure time.

It is expected that further observations will be made at ESO in early 1989, when Comet Halley will be more than 1500 million km away and also in 1990 (1900 million km) with the 3.6 m telescope or the new 3.5 m New Technology Telescope. However, at that time the comet will be significantly fainter than now and any further pictures will show less detail. Halley crosses the orbit of Uranus in April 1994, that of Neptune in February 2006 and reaches the most distant point in its orbit in April 2024, 5300 million km from the Sun.

Soviets Open Glonass System to West

The Soviet Union has released unprecedented details of its Glonass satellite navigation system and announced that the system is being offered for worldwide civil use.

Glonass is the Soviet Union's counterpart to the GPS system and like the US system is not yet operational, although both already have some useable satellites in orbit. No-one outside the USSR, however, is known to have any experience of using Glonass in order to confirm its accuracy.

The Glonass system is planned to comprise 21 operational satellites divided into three groups in separate orbital planes. Three spacecraft will be held on standby, although it was not clear whether on the ground or in orbit.

A two-phase launch schedule was announced with 1989-1990 being the deadline for the first 10-12 satellites and 1995 for the remainder. All satellites will be in 11 hr 15 min circular orbits at 19,100 km altitude and at 64.8 degree inclination to the Equator. ***ASN***

SATELLITE DIGEST — 214

Robert D. Christy

Continued from the June 1988 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1932, 1988-19A, 18957
Launched: 1420, 14 March 1988 from Tyuratam by F-1.
Spacecraft data: Combined satellite and final rocket stage, around 7 m long and 2 m diameter with a mass around 5000 kg. A slot-type radar aerial is fixed to one side of the body. Power is provided by a nuclear reactor.
Mission: Radar reconnaissance over ocean areas.
Orbit: 251 x 263 km, 89.66 min, 65.00 deg, maintained by a low thrust motor during the operational lifetime. On 20 May 1988, the nuclear reactor was separated and boosted to an orbit of 923 x 1011 km.

COSMOS 1933, 1988-20A, 18958
Launched: 1851, 15 March 1988 from Plesetsk, by F-2.
Spacecraft data: Possibly a truncated cone with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 635 x 661 km, 97.75 min, 82.54 deg.

IRS-1A, 1988-21A, 18960
Launched: 0643, 17 March 1988 from Tyuratam by A-1.
Spacecraft data: Three-axis stabilised, box-shaped body with solar panels at right angles to opposite sides. The mass is around 2000 kg.
Mission: Indian Remote Sensing satellite launched for India by the Soviet Union.
Orbit: 867 x 913 km, 102.84 min, 99.03 deg.

MOLNIYA-1 (72), 1988-22A, 18980
Launched: 2050, 17 March 1988 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 644 x 40564 km, 735.16 min, 62.87 deg, then lowered to 644 x 39730 km, 718.17 min, 62.87 deg to ensure daily repeats of the ground track.

COSMOS 1988-23A, 18985
Launched: 1408, 22 March 1988 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 952 x 1009 km, 104.76 min, 82.97 deg.

PROGRESS 35, 1988-24A, 18992
Launched: 2105*, 23 March 1988 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carring a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried equipment and consumable supplies to the resident crew of Mir. It docked with Kvant's aft-facing hatch at 2222 on 25 March. At 0136 on 5 May, it undocked and was commanded to re-enter later in the day.
Orbit: Initially 184 x 262 km, 88.89 min, 51.63 deg.

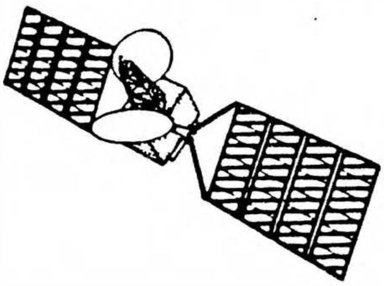
COSMOS 1935, 1988-25A, 19011
Launched: 1410, 24 March 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 167 x 333 km, 89.53 min, 67.17 deg, manoeuvrable.

SAN MARCO 5, 1988-26A, 19013
Launched: 1945, 25 March 1988 from the San Marco Platform by Scout.
Spacecraft data: 1 m diameter sphere with mass approx 240 kg.
Mission: Italian/American/West German payload studying the upper atmosphere.
Orbit: 263 x 618 km, 93.14 min, 3.00 deg.

COSMOS 1936, 1988-27A, 19015
Launched: 1200, 30 March 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 230 x 298 km, 89.80 min, 644.76 deg, manoeuvrable.

GORIZONT 15, 1988-28A, 19017
Launched: 0417, 31 March 1988 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links both within the USSR and abroad.
Orbit: Geosynchronous above 14 deg west longitude.

COSMOS 1937, 1988-29A, 19038
Launched: 1444, 5 April 1988 from Plesetsk by C-1.

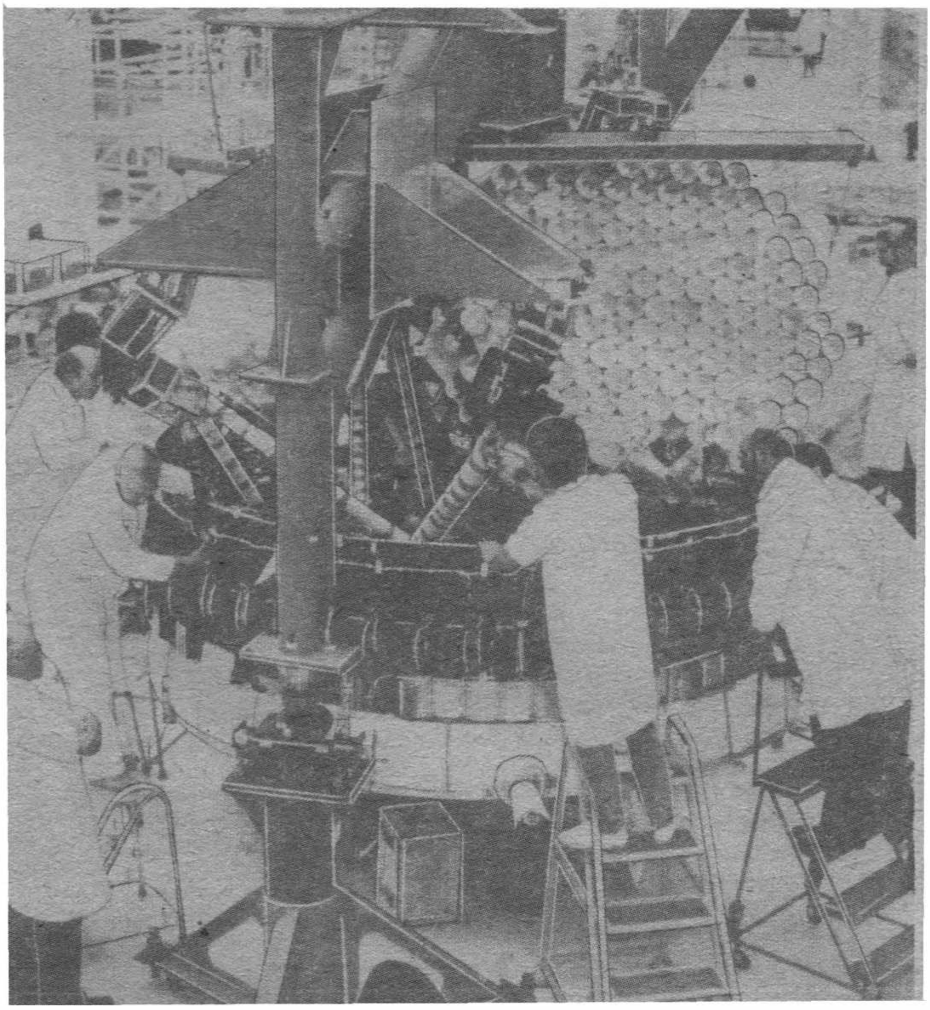


Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 769 x 806 km, 100.66 min, 74.05 deg.

COSMOS 1938, 1988-30A, 19041
Launched: 1115, 12 April 1988 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 13 days.
Orbit: 224 x 290 km, 89.69 min, 72.87 deg.

FOTON 1, 1988-31A, 19043
Launched: 1700, 14 April 1988 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Materials science experiments in micro-gravity, recovered after 14 days.
Orbit: 217 x 375 km, 90.44 min, 62.83 deg.

COSMOS 1939, 1988-32A, 19045
Launched: 0549, 20 April 1988 from Tyuratam by A-1.
Spacecraft data: A cylinder with a pair of sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at one end. The length is probably about 5 m, diameter 1.5 m and mass around 2000 kg. Stabilisation is by the use of momentum wheels.
Mission: Earth resources, remote sensing satellite in sun-synchronous orbit.
Orbit: 628 x 695 km, 98.03 min, 97.99 deg.



Intelsat VI team integrates the F2 satellite's antenna sub-system with the despun shelf as one of several steps that led to the build-up of the first flight vehicle *Hughes*

First Intelsat VI in Final Test

The world's largest commercial communication satellite, Intelsat VI F2, an international venture involving seven countries, is undergoing final testing in America before delivery later this year. It is scheduled for flight aboard the European Ariane rocket from Kourou, French Guiana, next year.

The F2 is the first flight vehicle in the Intelsat VI series of five satellites being built by Hughes Aircraft Company for Intelsat, a consortium of 114 countries whose satellite network provides two-thirds of the world's overseas telephone traffic and almost all international television.

As part of the massive undertaking to build the Intelsat VI series, Hughes Space and Communications Group subcontracted to companies from the United Kingdom, Canada, France, Italy, Japan and Germany.

"Intelsat VI is probably the most successful example of high technology international cooperation that's ever been accomplished," said Jerry Dutcher, programme manager. "It is the joint effort of more than 3000 people at Hughes and another 2000 around the world."

Mating of the F2's spun section with its despun section (pictured) was the final step in a vast assembly project.

The spun section, which houses the propulsion and control systems and most of the satellite's power system, spins at 30 rpm to produce stability during on-orbit operations.

The communications payload and most tracking, telemetry, and command units are housed in the despun portion, which remains stationary to keep the satellite's antenna pointing toward Earth. The satellite is capable of carrying 120,000 two-way telephone circuits and three TV channels.

European subcontractors on Intelsat VI to Hughes include UK firms Pilkington (solar cell covers) and British Aerospace (K band and C band reflectors, Ariane adaptor and separation band, and power electronics).

Space Art

Space artist David Hardy sparked off a flood of letters to the *Spaceflight* office following his article 'Who Needs Space Artists?' in the September/October 1986 issue of *Spaceflight*.

One point many readers were keen to pursue was the question of whether NASA had failed to obtain a high quality still photograph of Neil Armstrong on the Moon, and followers of the subsequent correspondence will have been fascinated by Douglas Arnold's in-depth and conclusive investigation into the issue published in last month's *Spaceflight*.

Last month (July) space artists from all over the world gathered for a workshop organised by the International Association of Astronomical Artists and the following articles written and illustrated by two of them, Ron Miller of the United States and David Hardy of the United Kingdom, serve to highlight the important role the artist now plays in the exploration of space.

by Ron Miller

Astronomy shares a very special quality with one or two other sciences: it has inspired a genre of fine art. Palaeontology has given us such fine painters as Charles Knight, Zdenek Burian and Jay Matternas, among many others, and medical illustration has created work of awesome and sublime surrealism.

Artwork in both examples has transcended its origins as "mere" illustration and can hang side by side with mainstream paintings in the world's most prestigious galleries. If the artist has the proper mind-set, then he or she is no longer fleshing out the scientist's fossils with muscle and skin, rendering a recreation in much the same vein as the police artist's recreation of a criminal's face; nor are they rendering as factually as possible the dissection of some human or animal organ. The artist can instead be carried away by his or her imagination into entirely new worlds of strange and wonderful beauty.

These worlds might be, without the benefit of science, otherwise invisible to the artist: made so by distance, size or time. Palaeontology, astronomy or anatomy act as windows. They only provide glimpses of possibilities, however. The panoramas they represent require the active presence of the artist; rather than windows into strange places, the sciences are perhaps more like the lenses of a camera that require the presence of a light-sensitive emulsion to give materiality to the images the lenses have gathered.

Unlike the landscape painter or portrait artist who paint what they see before them, the artist who is inspired by the vistas inherent in science is a necessary part of what is being depicted. That is, in every sense, what the scientific artist paints would not exist without his activity. He paints scenes that could not be seen in any other way than through the media of his artwork. As the camera's images are invisible until projected onto a screen or film, so too are many of the images of science until they are projected onto the artist's canvas. Only the artist can make visible what the palaeontologist studies or recreate the Earth as it existed millions of years ago.

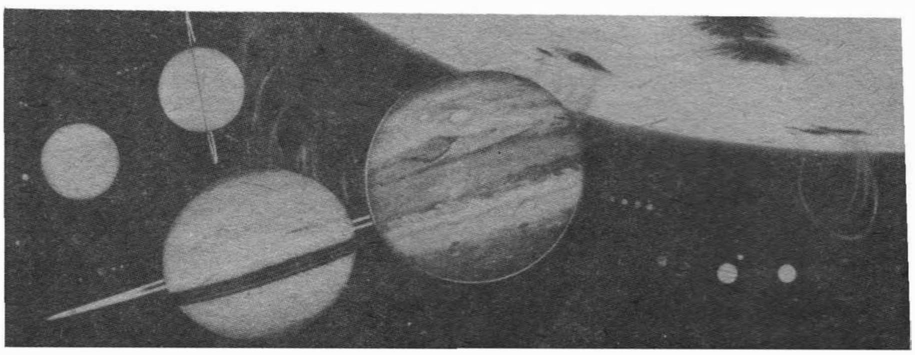
The artist can make the sciences real to the scientists themselves. As astronomers stray further and further away from the eyepieces of their telescopes, they have been gradually forgetting that they are studying real objects and real places. Stars and planets have been reduced to tables and graphs. And as astronomers become increasingly specialised, it becomes easy to forget the whole that one is studying part of. The subjects studied by astronomy are becoming abstract.

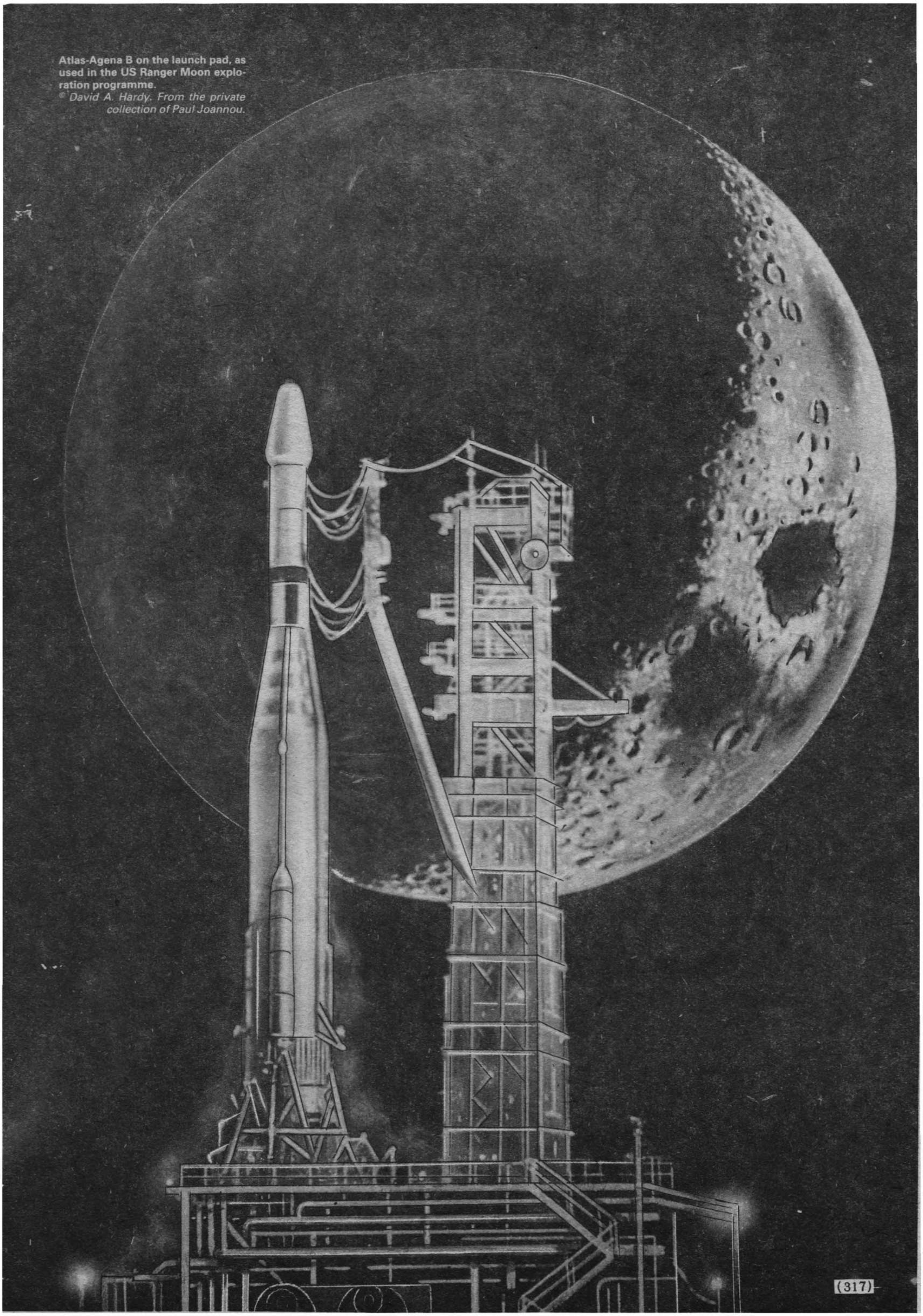
I remember all too well contacting the late Bart Bok with what I thought was a very simple question. I needed to get an idea of just how bright the Milky Way galaxy would look to the naked eye when seen from the distance of one of the Magellanic Clouds. I asked Dr. Bok because, of all people, he had devoted so many decades of his long career to the study of our galaxy. To my surprise and disapointment his answer was: "I've never thought of that before." How many astronomers have never stopped to consider what the objects of their study actually look like?

If astronomical art serves any practical function – though like any art form, it needn't – it can bring reality to places and objects that are of a necessity limited to abstract descriptions. More real, in fact, than the astronomer's data since the astronomical artist must draw upon many fields

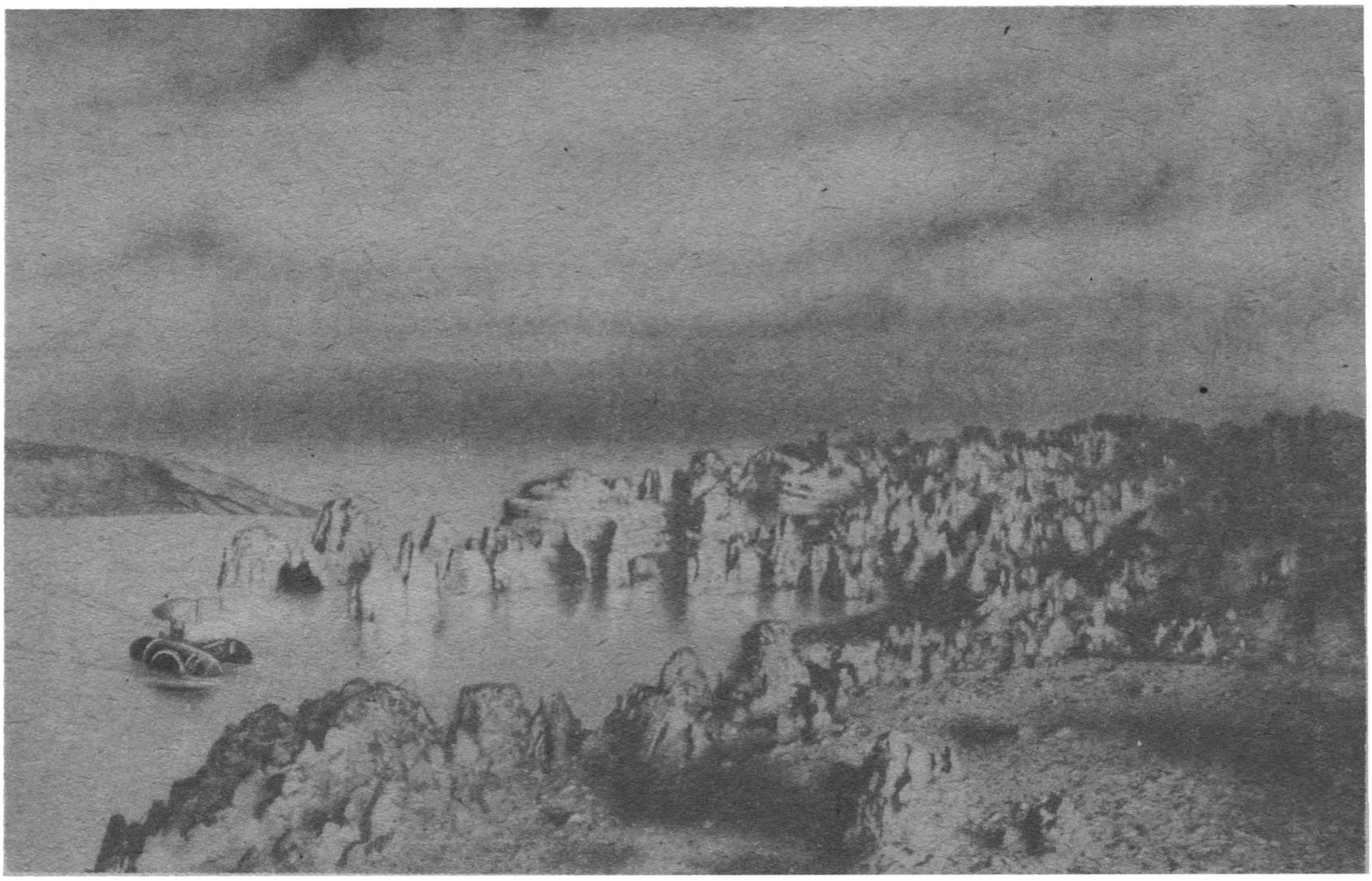
The solar system to scale.

Ron Miller



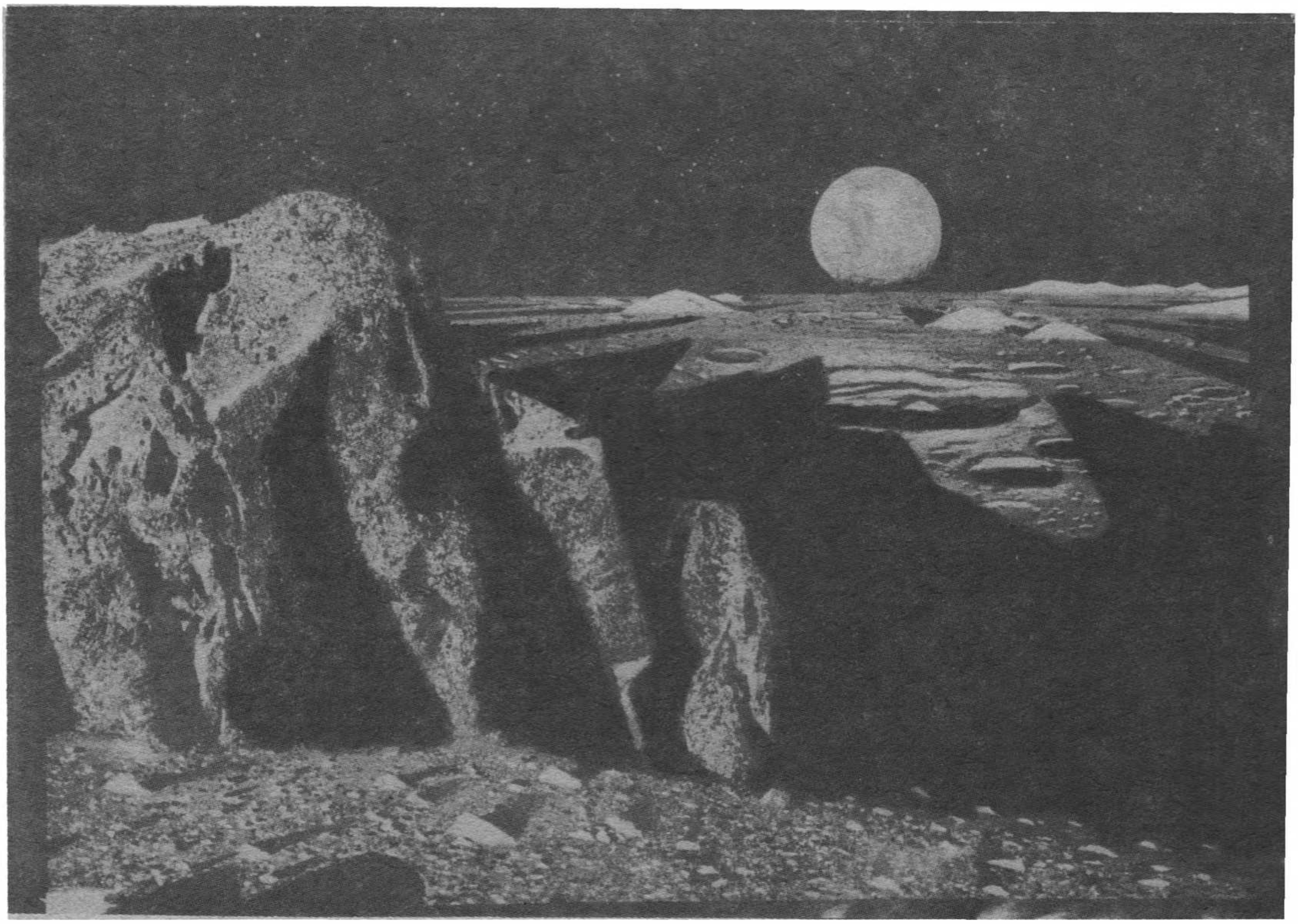


Atlas-Agena B on the launch pad, as used in the US Ranger Moon exploration programme.
© David A. Hardy. From the private collection of Paul Joannou.



Titan Floater by *Ron Miller* A methane-powered steamboat chugs around the frigid seas of Titan, gathering samples and taking photographs It only has to carry its own oxygen, burning the flammable atmosphere of the Saturian moon

Lunar Shadows by *Ron Miller* The rounded features of the lunar surface cast elongated shadows when the Sun is low making the hills and mountains seem craggy and precipitous



of study in order to create a complete scene. Any one astronomer or source of information cannot provide all that the artist needs. From one he may discover the shape of a landscape, from another its colour, from another the kinds of rocks that might be seen and their shape and texture, from another the colour of a sky, from another the appearance of a planet in that sky, and so on. Where science can be discordant, the art is coherent. Where it may not be possible or easy to visualise a place from the data provided by any one scientist, it is possible to do so in one glance by looking at an artist's reconstruction.

Astronomical art must be more than a mere reconstruction, however. It must convey more than the sum total of the cold facts it is based upon, or it is nothing more than a technical illustration, a diagram. It is the difference between an illustration of the muscles and tendons of the human face in a medical textbook and a portrait painted by a fine artist. Like the portraitist the astronomical artist, too, must try to convey something of the "personality" of a place. In speaking of the personality of landscapes, we mean what is actually called *picturesqueness* or *romance*. Not only what a place *is*, but what it is *like*.

I must admit that I am probably more interested in the romance of astronomy than its facts. While I make every effort to make my paintings as authentic as I possibly can – and often the time spent in research exceeds by a large factor the time spent actually painting – I subordinate accuracy to believability.

It is my strong feeling that all the scientific accuracy in the world is for nothing if no one believes that the scene they are looking at represents a real place. The stranger a place is the more effort needs to be spent in making it believable. If I have to put something really strange in the sky of a painting – strange, that is to a lay person – then it is very important that the foreground landscape, whether a known satellite or hypothetical planet, be as acceptable to the viewer as possible.

In fact, the stranger the object in the sky, the more "normal" the landscape beneath it ought to be. There should be at least one thing in the picture familiar to the average viewer. One resulting psychological effect is that once a viewer has "bought" part of a painting as real he is trapped into accepting the whole thing.

Part of this philosophy is to not overload a painting with facts. When this is done, every part of a painting becomes equally important. This is bad for the painting since it becomes dilute, it lacks a definite subject. It is far better to settle at the beginning on which one or two "facts" are to be the subject of the artwork and then to make every other detail subordinate to and supportive of them. Because astronomical painting depends so much upon a science for its subject matter, it is altogether too easy to become enamoured with the scientific content of a painting.

Astronomical art is a variety of landscape painting. Inspite of its name, it has, or should have, neither more nor less relationship to astronomy or astronautics than terrestrial landscape art has to geology or botany.

It may sometimes be necessary to alter a fact in order to make it correct. For example, when Saturn's rings are seen from most of its satellites they appear as a straight, white line bisecting the planet. This is because the satellites orbit in the same plane as the rings.

I discovered, however, that people were having a difficult time interpreting that white line. For example, when I had it crossing a crescent Saturn, I found people asking me if that was some sort of spaceship in the sky, or a kind of celestial bow and arrow, or something equally erroneous. So I tipped the rings a degree of two, just enough so that the rings could be seen going around the planet, but not enough to take away from the effect of a disk seen edge-on. People then understood what was happening in the painting; I made a fact right by making it wrong.

More often than not my paintings are destined for an audience of non-astronomers. I feel that it is more important to get them excited about the simple fact that there are other worlds in the sky than it is to try to instruct them in the details of planetary geology. If they have no initial interest in astronomy, then they certainly are not going to be interested in any of its finer details. My paintings are primers, not textbooks.

The result is that my paintings are simple, possessing, hopefully, a matter-of-factness about them that seems as though they had been painted from nature. I try to get between the viewer and the subject of the painting as little as possible: that is, I do not want the viewer to be constantly aware that he is looking at an "artist's impression", a concept that immediately carries with it a taint of the wholly imaginary and speculative. I try to maintain a naturalness about the landscapes. This is often made difficult by the very nature of astronomical art: I paint many scenes that are not possible to actually visit – at least not at the present time.

One of the dangers of inventing scenery, even if one knows that such a place actually exists, is that the artist must place every item that makes up the picture in place consciously. The danger lies in the loss of the randomness that makes natural scenes look natural.

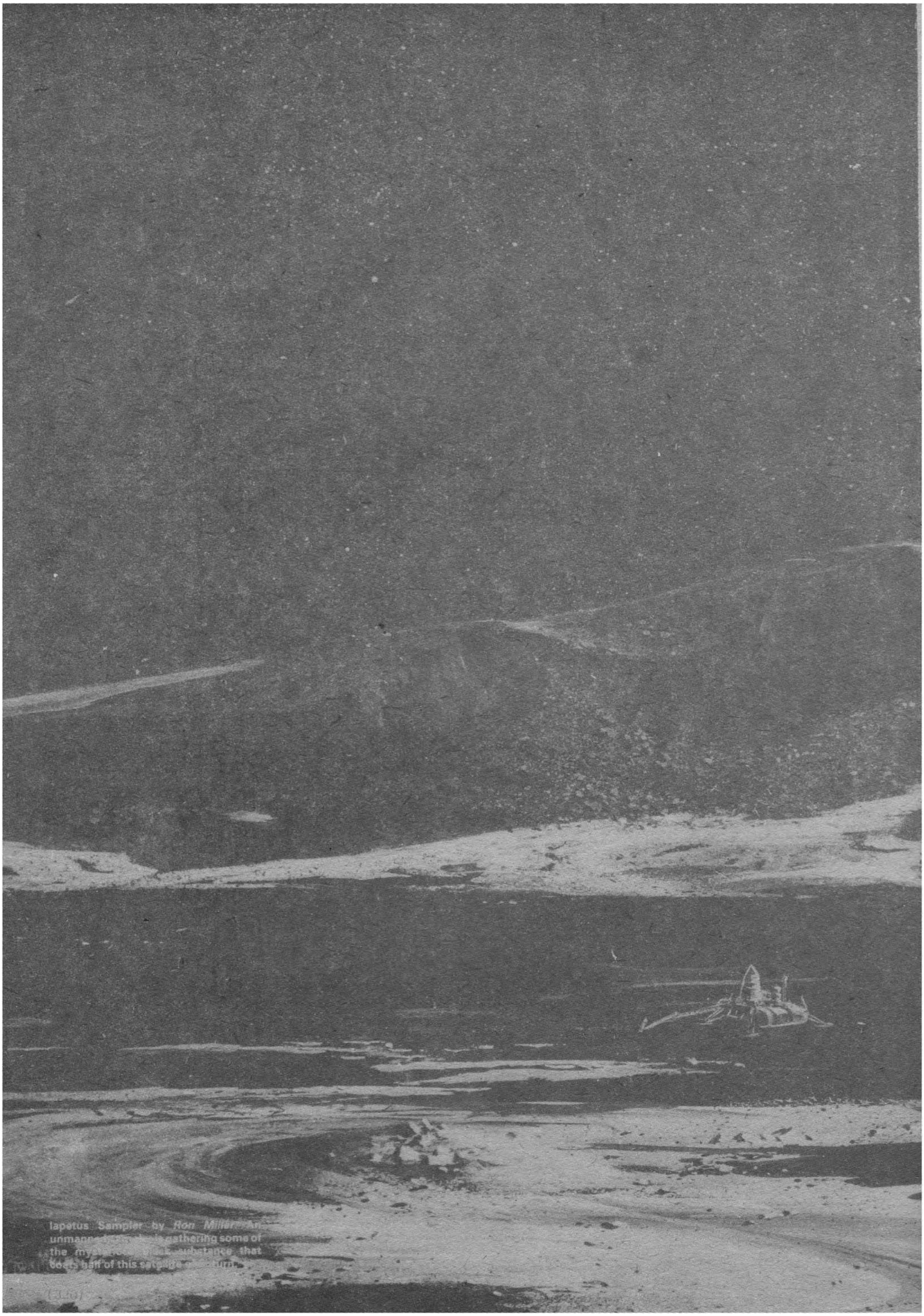
There is a tendency for the landscapes to look too neat and orderly. Chesley Bonestell's paintings often had a park-like look to them for this reason. I combat this by trying to introduce as many random factors as I can: spattering pebbles and rocks into a painting by flicking a brush over it; texturing rocks and mountains with wet sponges; spattering, using crumpled papers and other techniques. Once a random base is down, the fussier finishing of the painting will not endanger the naturalness of the finished product.

I will often use photographic reference, rather than make up a landscape out of whole cloth. Usually this is used as a jumping-off point, rather than actually copied. It acts as a reminder to avoid getting too neat and orderly. Sometimes as many as half a dozen or more photos will act as inspirations for a single painting: from one may come an idea for a fold in a mountain, from another an interesting rock formation, and so on. Over the years I have accumulated a "morgue", or picture reference collection, that fills a pair of filing cabinets, to say nothing of several bookcases.

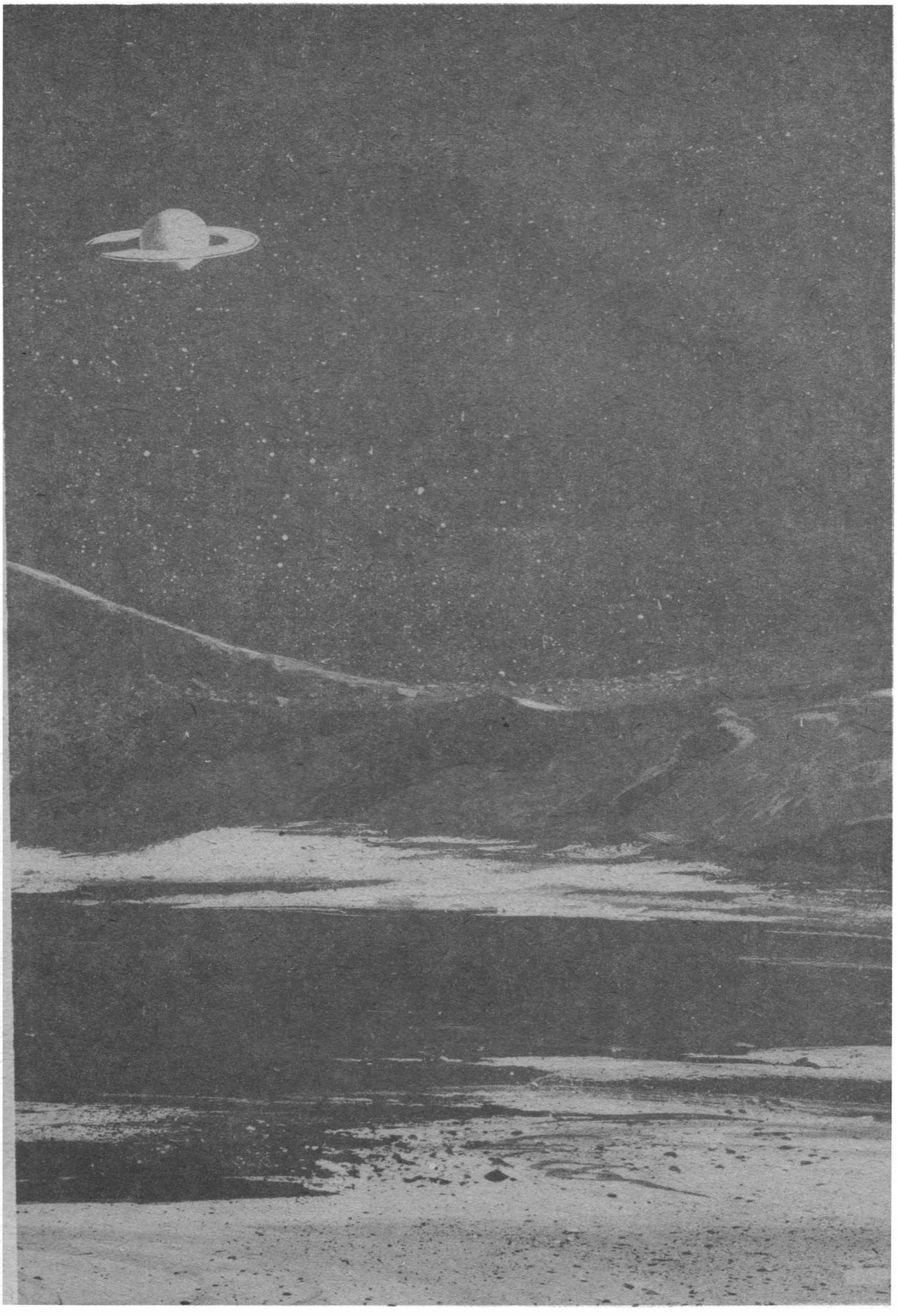
Unless an artist is thoroughly familiar with a subject, he should never invent it. He should always work from some sort of reference, whether it be a shoe, a flower, a spacecraft or a human figure. It is far, far too easy to get something, if not actually wrong, at best unconvincing.

All the scientific accuracy in the world is for nothing if no one believes they are looking at a real place.

If I have any particular goal in mind for my astronomical art it is to make people realise that there are not only other worlds in the universe, but that they are often as interesting and strange as our own Earth. I hope to make people understand that as weird as some of the places in our own solar system can be, they will not seem totally unfamiliar. I hope that I, and my fellow astronomical painters, will be fulfilling the very important function that several of America's Hudson River School painters did in the late 19th century. Some of them, such as Albert Bierstadt and Thomas Moran, were among the first to bring back images of what was to become Yellowstone and Yosemite national parks. As persuasive as the written reports of the formal expeditions were, it was the giant paintings by these artists that, sent touring around the country, sold the American people and their Congress on the idea of preserving these special and amazing places. Words were one thing, but romantic images of the West's fantastic landscapes made them both real and unforgettable. I hope that I can do the same for our neighbours in space.



Iapetus Sampler by *Ron Miller*. An unmanned [illegible] gathering some of the my[illegible] substance that [illegible] half of this satellite [illegible]



Exploring Space with a Paintbrush

by David A. Hardy

Whereas in the 'early days' the number of artists working in the space field could be counted on one hand, today there are so many that an International Association of Astronomical Artists (more conveniently known as the IAAA) has been formed in the USA. Naturally it includes most of the better known US artists – Michael Carroll, Don Davis, Don Dixon, William Hartmann, Paul Hudson, Pamela Lee, Robert McCall, Ron Miller, Kim Poor, Rick Sternbach – around 50 active artists in all, so too many to list here. Of these only two or three are female, though these are excellent.

Also included is Alan Bean, who is of course better known as an astronaut. He is one of two artists envied by all the others, because he has actually been in space (and to the Moon). The other is the Soviet cosmonaut Alexei Leonov, the first man to 'walk' in space, in March 1965.

Leonov has produced several books in collaboration with Andrei Sokolov. Their work is excellent, but differs from that of western artists, being much more 'painterly' – obvious oil paintings, often with the paint laid on thickly (impasto). It is also often very large. When working on illustrations, I often work 'same size', or at most 'half up'.

Western space artists, generally, produce much more realistic work, often using the airbrush as an aid. My own approach has always been to attempt to "photograph the unphotographable", which I sometimes enhance by using 'wide angle' effects, or showing the internal flare produced by a camera lens pointing into a bright light.

Over the last few years the US contingent of the IAAA has held workshops in Hawaii and Death Valley – in other words, spots on Earth's surface which resemble as closely as possible the geology and conditions of our neighbour worlds like the Moon and Mars – where they sketch, take photographs, exchange notes and tips, collect reference material – and have a little fun. Last month (July) they went to Iceland and were joined by space artists from Europe (including myself) and a group of around a dozen Soviet artists – including Leonov and Sokolov. Further exchanges with Moscow are planned.

Can we hope that such cooperation between artists might one day be reflected by similar collaboration between Eastern and Western scientists – an international expedition to Mars, perhaps?

Naturally there is now considerable competition among space artists for the illustration work available. Kim Poor, who is President of the IAAA, makes his living by selling original paintings and prints of his own work and that of others. Ludek Pesek, a Czechoslovakian artist who lives in Switzerland, did many illustrations for the *National Geographic Magazine* and for books, and in Britain there are several space artists, some more active than others. Paul Doherty, an excellent observational astronomer and well known in the British Astronomical Association, now often produces work for The Sky at Night and is Art Editor of the magazine *Astronomy Now*. Ed Buckley and Gavin Roberts work mainly in Scotland with Duncan Lunan and ASTRA, and David Early holds occasional exhibitions of his landscapes. Julian Baum (whose work is often seen in ***Spaceflight***) makes models and combines photographs of these with painted backgrounds. We plan to collaborate.

Over the years my work has appeared in books and on covers and jackets, magazines (scientific, SF or general), on record sleeves, on TV, in advertising from newspapers to 48-sheet (building-size) posters, and in movies.

The media I use vary from pen to oils, though my preference is for gouache or acrylics. In recent years, however, I have begun to combine photography and use computer graphics, which are the most exciting development yet. Needless to say, I am also writing this using a word processor! Such is the acceleration in technology over the last 30 years or so – and much of this was made possible by the space programme.

Back in the 1950's a great deal of imagination could be used by the artist in designing spacecraft, and the details of planetary landscapes had to be based purely on telescopic observations. Today the wealth of data, information and images available make the space artist's work more accurate, but as a result often more difficult.

The skies of Mars have changed from blue to pink and Venus has lost its oceans of soda-water (based on a carbon dioxide atmosphere) to become a hostile, sulphurous planet, with volcanoes and lightning bolts.

Mercury is now remarkably moonlike and Jupiter and Uranus, like Saturn, have their own ring systems.

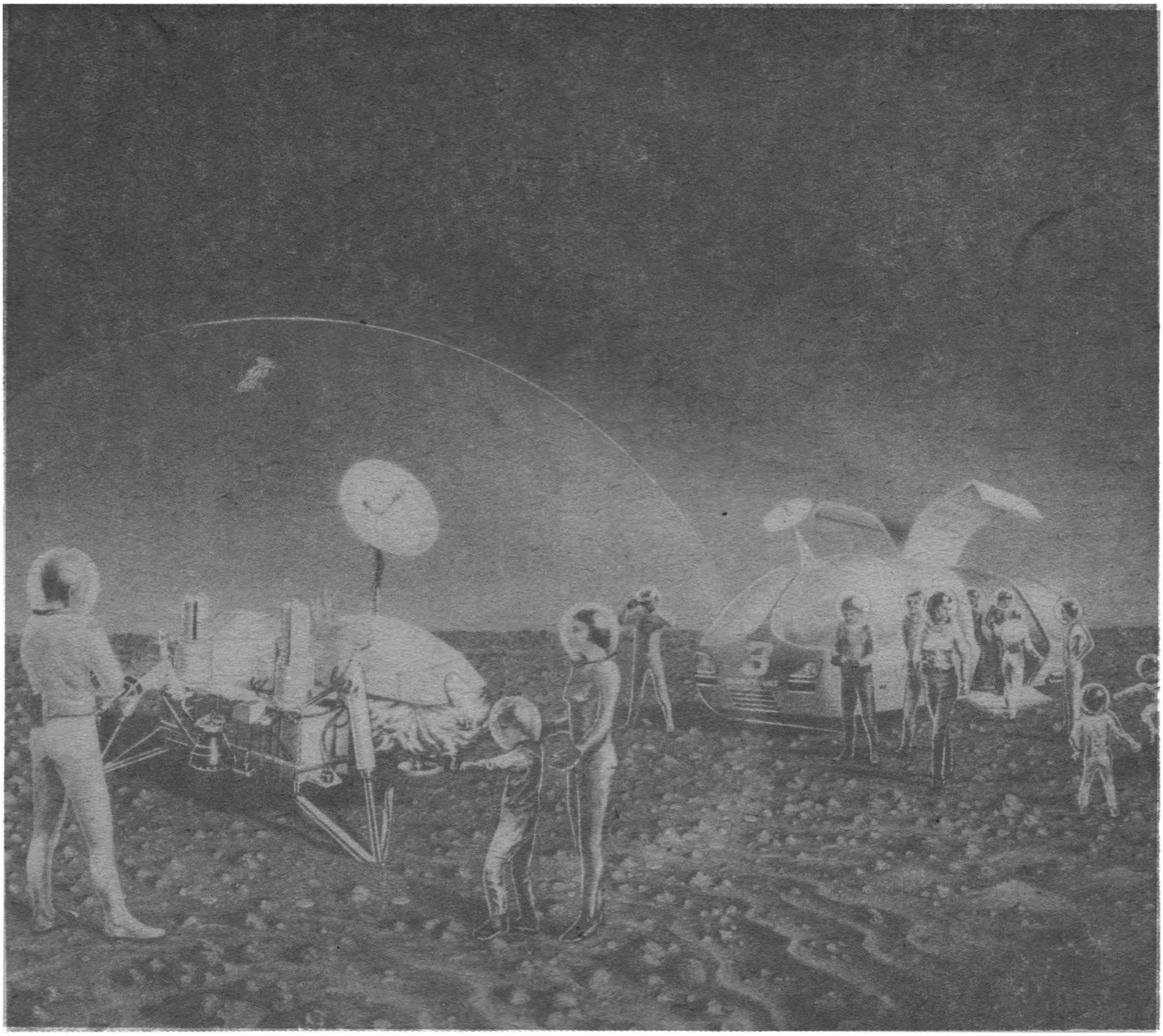
As each new space probe was despatched, and each new discovery made, artists revised their earlier renderings – and they will continue to do so as humankind expands into space. Despite the intrusion of the camera into the domain of artists, the paintbrush (and airbrush) will always have been there first.

It was the Chesley Bonestell-Willy Ley book *The Conquest of Space* which, at the age of 14, 'turned me on' to astronomical art. I could hardly believe that the illustrations were not photographs – except that no-one had been to the Moon, Mars, Venus or the moons of Jupiter and Saturn. I even showed them to my Art Master at school, who first thought that they were retouched photos, then explained that they must be the product of painstaking brushwork. Before I left school, in 1952, there was a small exhibition entitled 'Interplanetary Paintings by David Hardy, 5A' at the school's open day... During that year I also joined the BIS. At that time Ralph Smith was of course producing wonderful illustrations for books like Arthur C. Clarke's *The Exploration of Space*, which also inspired my interest in the subject of space travel, as well as space art

Having produced a number of exhibition paintings for the BIS, showing how outer space could be explored, I was introduced to Patrick Moore in 1954 by a friend and fellow-member, Michael Guest. Patrick's *Guide to the Moon* had just been published, with considerable success, and he was writing a sequel, *Guide to the Planets*. As it happened, this was already being illustrated but Patrick asked me to illustrate another book, *Suns, Myths and Men*.

As I was about to join the RAF for my National Service, I had to produce eight black-and-white drawings in five days. I used scraperboard – a technique in which a black surface is scratched to leave white lines (ideal for space subjects) – and posted the illustrations on my way to the railway station.

This became the first in a long and very pleasant series of collaborations, resulting in books such as *Astronomy*



Above: A glimpse of the future? Tourists visit Viking 1 on its original landing site, protected by an energy dome (From *Galactic Tours* by David Hardy and Bob Shaw). *© David A. Hardy.*

Right: A visit to Iceland inspired this version of tourists on a highly seismic world orbiting a double star, one in eclipse. (From *Galactic Tours*). *© David A. Hardy.*

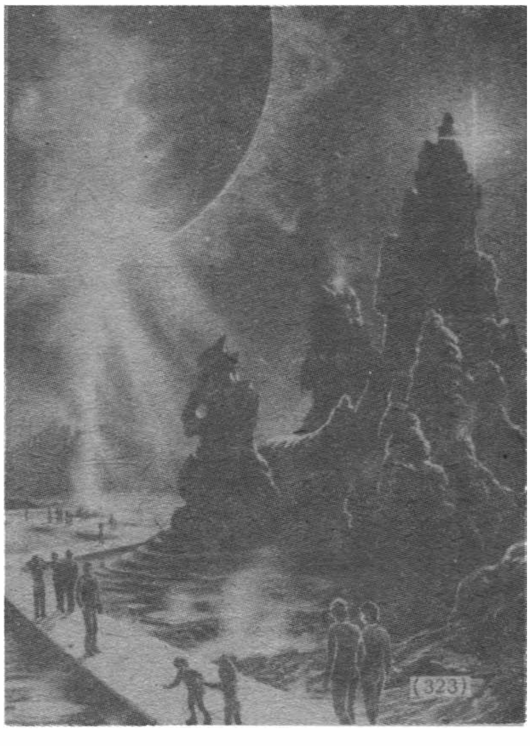
(Oldbourne Press), *Space* (Lutterworth), *Astronomy for 'O' Level* (Duckworth), and *Mars the Red World* (World's Work). After *Mars the Red World*, World's Work, which was part of the Heinemann Group, was interested in further books: Patrick encouraged me to write these myself, as a number of astronomical articles by me had recently been published in various magazines.

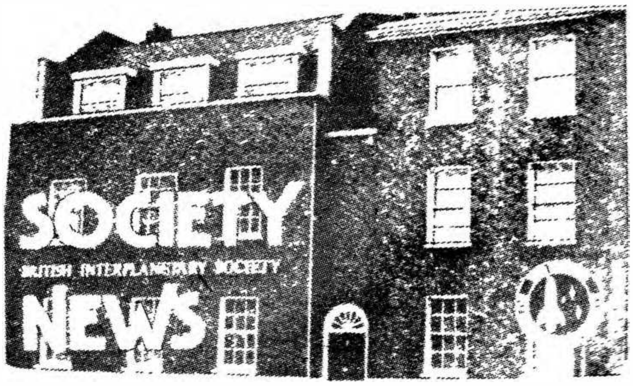
As a result, *The Solar System* was published in 1975 and *Rockets and Satellites* in 1976. I then branched into subjects sometimes only loosely concerned with astronomy: *Air and Weather, Light and Sight,* and *Energy and the Future.*

Probably the most successful book that Patrick Moore and I did together was *Challenge of the Stars* (Mitchell Beazley, 1972), which was reprinted in a much updated edition in 1978, to coincide with the release of the film *Star Wars*. This edition even included a spherical 'battle station' – which I painted before I saw the 'Death Star', though no-one will believe me now! We had originally intended to produce a book with that title back in 1954 – but no publisher would accept it, saying that it was too speculative!

My first television work also came about through Patrick Moore and his BBC series *The Sky at Night* which began in 1957. I produced many landscapes of other planets and satellites for this, originally all in black and white of course, as well as some diagrams. Unfortunately, these have long-since disappeared.

My own major book to date is *Atlas of the Solar System*, first published by World's Work in 1982, then in an updated version by Octopus in 1986. Other space artists have now also produced their own books.





43rd ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the 43rd ANNUAL GENERAL MEETING of the BRITISH INTERPLANETARY SOCIETY Limited will be held in the Society's Conference Room at 27/29 South Lambeth Road, London, SW8 1SZ on 17 September 1988 at 12 noon precisely.

Attendance is restricted to Fellows of the Society. Admission is by ticket. Those wishing to attend must apply for tickets not later than 10 days before the date of the meeting.

AGENDA

1. To receive the Report of the Council on the Society's Affairs for the year to 31 December 1987.

2. To receive the Society's Balance Sheet and Accounts for the year ended 31 December 1987 and the Auditors Report thereon.

3. To appoint Auditors and determine the method of fixing their renumeration. The present Auditors have expressed their interest in continuing in Office.

4. To propose a SPECIAL RESOLUTION.-
   (a) That Clause 60 of the Articles of Association of the Society be amended to read 60 (a).

   (b) That a new Clause to be numbered 60(b) be inserted, to read as follows:-

   (60b) The Executive Secretary shall be charged with the duty of creating and maintaining in proper condition Society and Library Archive Collections, provided that no item designated by the Council as forming part of the Society's Archival Collection shall be sold or otherwise disposed of without the prior approval of a Resolution to be passed by not less than 75% of the vote of the Fellows of the Society, such Resolution to be decided by a poll taken by postal ballot of the Fellows of the Society only in such manner as the Council shall direct.

5. To elect four Members of the Council of the Society. In accordance with Article 43. The following Members of the Council will retire at the meeting:

Dr. R.D. Gould	Dr. L.R. Shepherd
Capt. C.R. Hume	G.M. Webb

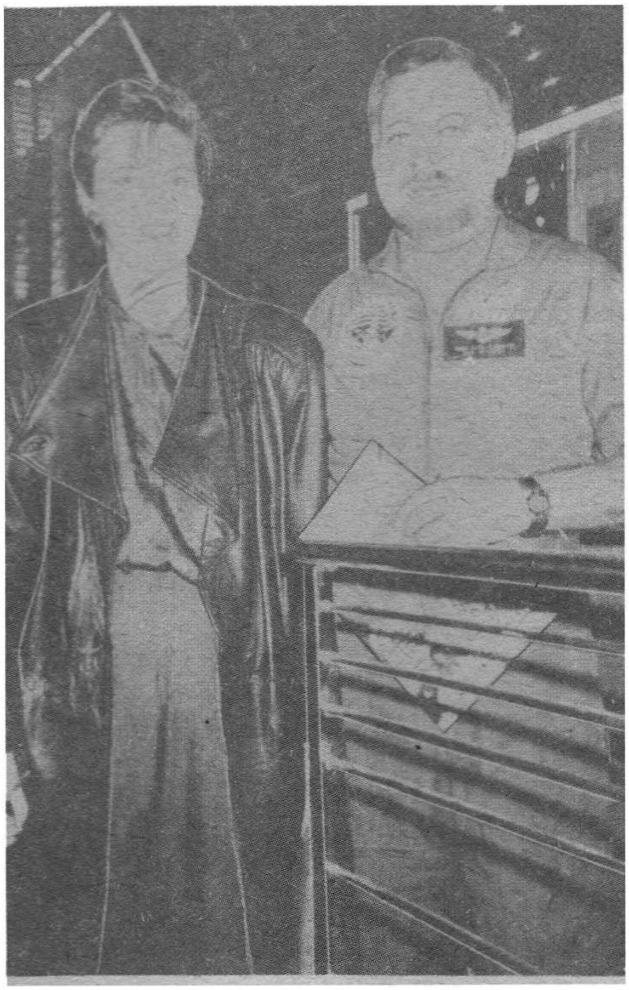
   If the number of nominations exceeds the number of vacancies, election will be by postal ballot in accordance with Article 44. The final date for the receipt of ballot papers will be 31 January 1989.

6. General Discussion.

7. Closing remarks by President.

By Order of the Council
L.J. CARTER
Executive Secretary

A Fellow who cannot be personally present at the meeting may appoint by proxy some other person, who must be a Fellow of the Society, to attend and vote on his behalf, subject, however, to the proviso that a proxy cannot vote except on a poll.



Shuttle Astronaut

BIS staff member Suszann Parry met up with US Shuttle astronaut Paul Scully-Power at the recent opening in London of *Space Adventure*, a new 'simulator' which takes participants on an imaginary journey through the solar system.

Paul Scully-Power became the first oceanographer in space as a crew member of Challenger on mission 41G in 1984 and Mrs Parry presented him with a collection of Society souvenirs to take back to the Johnson Space Center where he is now an instructor in the astronaut office.

Space Adventure, which provides a realistic insight into space travel for children, is located in Tooley Street, London.

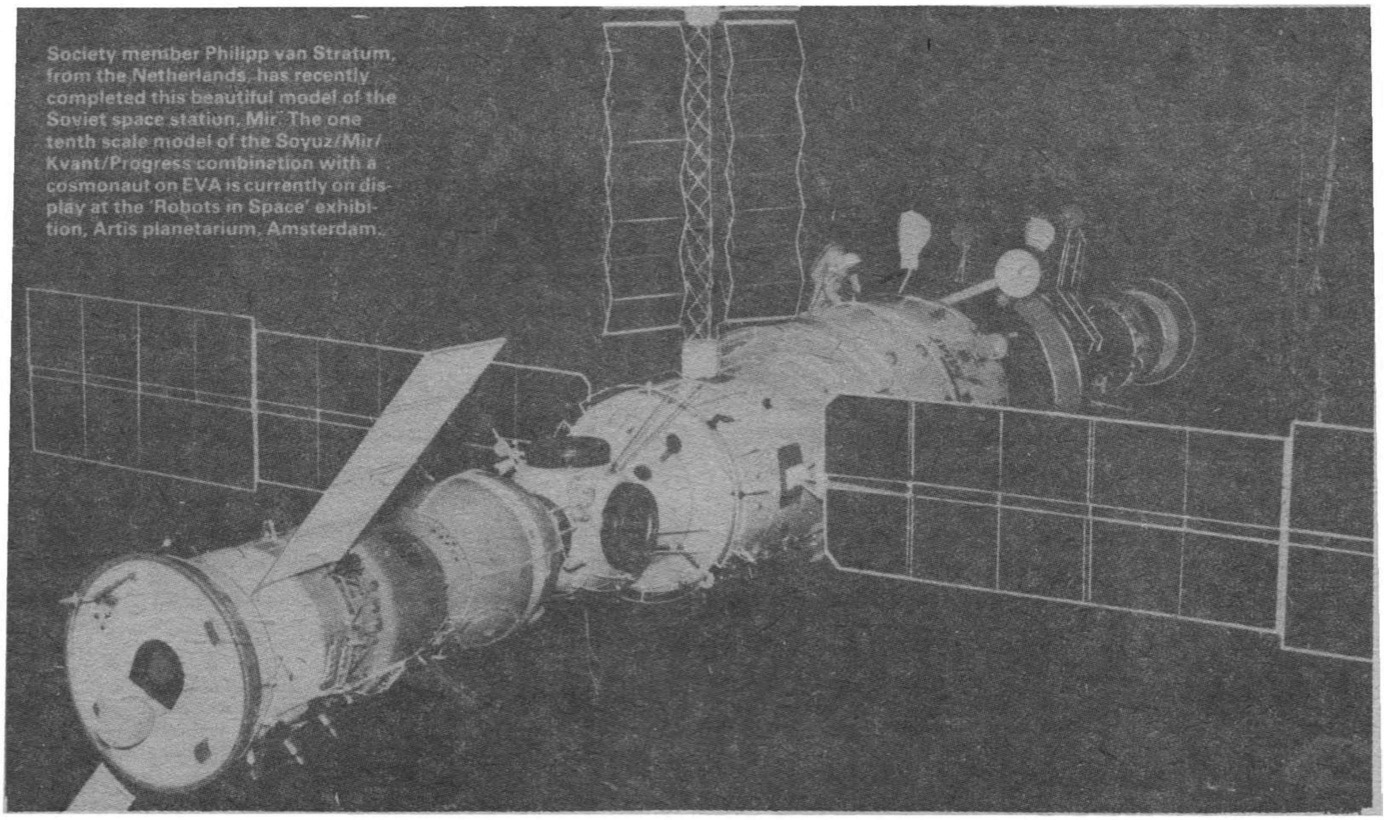
Society Officers for 1988

At its meeting in March, the BIS Council elected Mr. G.W. Childs as President (*Spaceflight*, May 1988, p.209) and Professor I.E. Smith and Mr. A.T. Lawton as Vice-President.

Since 1978, Prof. I.E. Smith has held a personal Chair at the Cranfield Institute of Technology where his work, since 1975, has been in the field of Energy and Energy Conservation. His interest in rocket propulsion extends back to the 1950's, having joined the Blue Streak Propulsion Team at Rolls Royce in 1958.

Tony Lawton has been a Council member for many years and served as President from 1982 to 1984. Recently retired from a senior technical position at Thorn EMI, he is continuing his interests in the Soviet space programme and a number of astronomical areas.

Following the recent elections to Council reported in the April issue of ***Spaceflight*** (p.164), the BIS Council for 1988 is as follows: G.W. Childs (President); Prof. I.E. Smith, A.T. Lawton (Vice-presidents); R.A. Buckland, M.R. Fry, Dr. Gould, Prof G.V. Groves, C.R. Hume, Dr. L.R. Shepherd, G.V.E. Thompson, C.R. Turner, G.M. Webb.



Society member Philipp van Stratum, from the Netherlands, has recently completed this beautiful model of the Soviet space station, Mir. The one tenth scale model of the Soyuz/Mir/Kvant/Progress combination with a cosmonaut on EVA is currently on display at the 'Robots in Space' exhibition, Artis planetarium, Amsterdam.

SPACE '88 – Not to be Missed

The Society's SPACE '88, **the biggest space conference in the UK this year, is shaping up as a major event with a host of internationally renowned speakers.**

It will be held at the attractive south coast resort of Hastings, Sussex, at the White Rock Theatre and Falaise Hall from Friday evening, September 30 to Sunday, October 2.

SPACE '88, the theme of which is 'Space – Man in the 21st Century', will be the ideal opportunity to hear and meet some of the top people in the space business.

Among the international names will be speakers from NASA (Dr. I. Bekey, of the Office of Exploration), ESA (Dr. R. Reinhard), and JPL (Dr. Bill McLaughlin, whose regular 'Space at JPL' column in ***Spaceflight*** is widely acclaimed).

The Saturday evening Banquet promises to be a highly entertaining occasion with guest speakers Patrick Moore, David Hughes (a specialist on cometary exploration), and Alan Bond (co-originator of Hotol), to follow a sumptuous meal.

Other UK-based speakers during **SPACE '88** will include Peter Conchie and Bob Parkinson of British Aerospace, Roy Gibson special adviser to Inmarsat, Dr. Garry Hunt and Douglas Arnold.

Commenting on the arrangements for **SPACE '88,** Mr. Len Carter, Executive Secretary, expressed delight with the programme.

"We shall be looking into the space future of the 21st Century as realistically as possible taking in the developments scheduled for the 1990's on the way" he said.

Full details of the exciting weekend programme and special discount rates for Society members appear on pp.326-7.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Members may bring one guest.

30 Sept – 2 October 1988 Conference

SPACE '88

Major weekend space conference, including varied programme of lectures and full social programme.

Venue: White Rock Theatre, Hastings, Sussex, UK

Registration
Forms and further details are available from the Society by sending 20p stamp or international reply coupon.

15 November 1988, 10-4.30 Symposium

EXTENDING THE SPACE INFRASTRUCTURE

The reports of the National Commission on Space and Dr. Sally Ride have paved the way for a new innovative space policy in the United States. It encompasses the setting up of bases on the Moon and manned exploration of the planet Mars. The BIS is holding a two part symposium on the issues raised by this exciting new prospect.

The purpose of the symposium is to start European discussion on the subject, including a review of American proposals, and proposals for suitable European contributions to the programme.

The symposium covers the following subjects:
- Infrastructure planning
- Orbital transfer systems
- Geostationary operations
- Lunar transportation system
- Lunar bases
- Planetary exploration systems
- Exploitation of the solar system.

The first part of the symposium will be held on 14 July 1988 and the second part will be held on 15 November 1988.

Offers of Papers are invited
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms are available from the Society. Please enclose SAE.

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except August) between 5.30 pm and 7 pm. Membership cards must be produced.

SPACE '88

The theme of Space '88 is a topical one with the current debate on such major project initiatives as a joint US and Soviet mission to Mars, a return to the Moon, the development of Hotol and a European manned space programme – all of which will have a significant impact on life in the next century.

On behalf of the Society I am pleased to extend this invitation to all Society members and readers of *Spaceflight* to attend Space '88. You have my best wishes for an enjoyable and creative weekend.

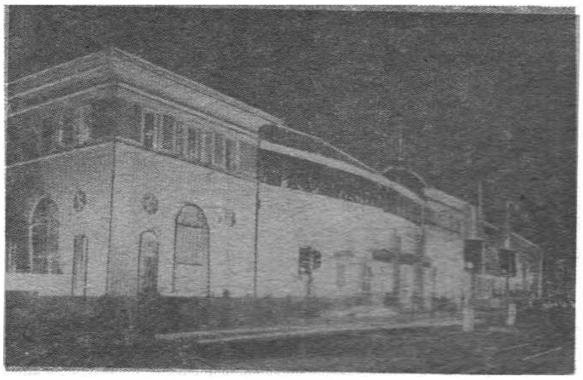
G.W. Childs
BIS President

• Mr. Roy Gibson.

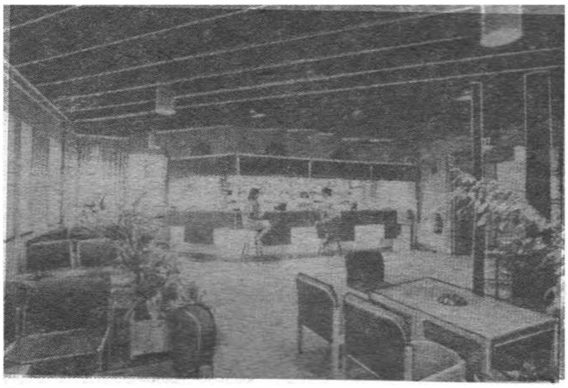
Man in the

PROGR–

White Rock Theatre – venue for SPACE '88.



The comfortable lounge bar of the White Rock Theatre.



Hastings – attractive seaside location.

Pictures courtesy Hastings Borough Council

Friday 30th September

4.00 – 6.30 pm Registration in the Foyer of the White Rock Theatre, Hastings.

8.00 pm Civic Reception and Dance at the White Rock Theatre. Supper will be served at 9.30 pm.

Saturday 1st October

9.30 am **OPENING CEREMONY**

Welcome to Hastings by the Right Worshipful the Mayor, Councillor Mrs. S. Barr.

Welcome to Space '88 by G.W. Childs, the Society's President.

10.00 am **SPACE PHILOSOPHY**

A Philosophy of Space Exploration
Dr. W.I. McLaughlin

Space & Mankind: The Writer's View
Dr. L. Suid

Spin-Off: Present Indicatives
Dr. N. Loukes

Britain in Space: A Philosophical Approach
Mr. R. Gibson

Luncheon

2.00 pm **AEROSPACE VEHICLES**

Aerospace Vehicle Operations in the 21st Century
Mr. P.J. Conchie

The Future Role of Trans-Atmospheric Vehicles
Mr. A.T. Lawton

Information Technology for Future Space Systems
Mr. P. Norris

SPACE APPLICATIONS AND TECHNIQUES

The Future of Satellite Mobile Communications
Mr. D. Webber
Inmarsat

Making Semi-Conductors in Space
Mr. A.T. Lawton,

Space Coolers
Dr. D. Llewellyn-Jones

• Dr. Bill McLaughlin.

• Mr. Peter Conchie.

21st Century

AMME

7 30 pm — BANQUET in Falaise Hall, White Rock Gardens, Hastings, with speeches by Guests of Honour
Patrick Moore, noted author and broadcaster.
David Hughes, authority on Halley's Comet.
Alan Bond, originator of the Hotol concept.

Sunday 2nd October

9 30 pm — **EXPLORATION OF THE SOLAR SYSTEM**

Planet Earth & The Future of Remote Sensing
H.J.P. Arnold

Space Biology and Medicine: the 21st Century
Dr. M.J.F. Fowler

The Human Exploration of Space
Dr. I. Bekey

Cities of the Moon?
Dr. R.C. Parkinson

Some Aspects of a Mars Base
Dr. G.E. Hunt

Luncheon

2 00 pm — **EXPLORING COMETS & ASTEROIDS**
The Importance of Sample Retrieval from Comets
Dr. D.W. Hughes

A Review of Future Comet Missions
Dr. R. Reinhard

Terraforming Other Worlds
M.J. Fogg

Tea and Coffee will be served during mid-morning and afternoon breaks.

▲ TV Astronomer

Astronomer and TV presenter Patrick Moore, who was awarded a CBE in the recent Queen's Birthday Honours, is a guest of honour at Saturday evening's banquet in the Failaise Hall, Hastings.

TOP SPEAKERS

Special Discounts for Society Members

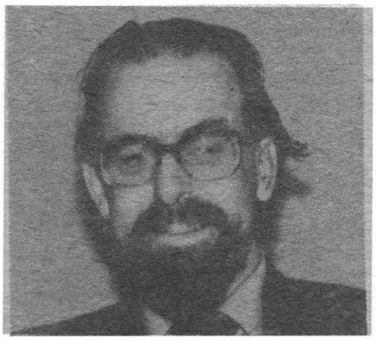
SPACE '88 is open to anyone with an interest in space and there are substantial discount rates for all Society members who wish to attend.

Several hundred people are expected to attend SPACE '88 and pre-booking, especially if banquet tickets are required, is strongly recommended.

Registration forms together with an information pack on Hastings will be sent on receipt of a 20p stamp or an international reply coupon. Please write to SPACE '88, The British Interplanetary Society, 27/29 South Lambeth Road, London, SW8 1SZ, England.

The scale of charges, which covers registration, civic reception and dance, and mid-morning and mid-afternoon refreshments, is as follows:

Non-Members	£55	(US$90)
Society Members	£40	(US$76)
Members under the age of 21	£20	(US$36)
Opening Civic Reception	FREE	
Accompanying Person	£10	(US$18)
Banquet	£22	(US$40)



• Dr. Bob Parkinson.

Solar System Exploration

Sir, I have been following with interest ***Spaceflight*** articles on the future exploration of the more primitive bodies of our Solar System – the asteroids and comets. I refer particularly to the CRAF mission [1] and the proposed (but now modified) Galileo flyby of an asteroid en route to Jupiter [2].

These missions, while not perhaps as glamorous as Mars landings or Neptune flybys, are extremely important to our understanding of the early Solar System and I look forward to their implementation. However, one idea has occurred to me and – if no-one has thought of it before – I would like to propose it.

The gravitationally stable points in our Earth/Moon system are ideal collecting grounds for asteroidal and cometary material. Particularly the Lagrangian points four and five, which are the counterparts to the Jovian Trojan points. If material has collected at these points, it would be a (relatively) simple task to fly out 240 thousand miles and examine it, perhaps even to bring samples back to Earth. And all in a matter of days, rather than months or years.

Perhaps the forthcoming Lunar Geoscience Observer [3] could investigate the area as part of its mission.

This whole idea of course depends upon there being material *at* the Lagrange points. I seem to remember one of the Gemini flights made a short sequence of observations of the area – were they successful? And, have any other more sophisticated observations been made since? Perhaps you, or your readers could enlighten me...

ROBERT GLOVER
Sheffield, England

References

1 ***Spaceflight***, December 1985, p 452
2 ***Spaceflight***, June 1985, p 257
3 ***Spaceflight***, July 1985, p 302

Canadian Upper Atmosphere Experiment

Sir, Readers may be curious about the "Wide Angle Michelson Doppler Imaging Interferometer" listed in the Space Shuttle Manifest for STS-49 in April 1991. Having participated in the design of this instrument, I can give a brief overview of its development and objectives.

WAMDII is a Canadian experiment intended to observe the speed, direction and temperature of upper atmospheric winds. Previous ground-based measurements have provided only imprecise and short-term information about these winds.

WAMDII will observe the light of the aurora borealis and airglow. This light is produced by the emission of molecules such as nitrogen and oxygen at altitudes between 80 and 250 km. These air molecules travel as winds with velocities of up to a kilometre per second, reaching temperatures of several hundred degees Celsius.

The light emitted by the molecules carries a great deal of information. The frequency (colour) of the emission depends on its velocity with respect to the satellite: blue-shifted for approaching, red-shifted for receeding, according to the Doppler effect. The 'pureness' of the colour (technically, the spectral width of the emission lines) is a measure of the temperature of the molecules. Finally, the intensity of the emission indicates the relative excitation of the air molecules.

WAMDII is based on a solid glass "interferometer", polished and assembled to state-of-the-art tolerances. This device, invented by the American physicist Michelson in the 1880's, measures the 'beat pattern' of interfering beams of auroral light, and from the characteristics of this pattern can infer speed and temperature. The instrument employs a CCD light detector array to make the measurements at several thousand points simultaneously in a wide field of view. Data are communicated by telemetry to a ground station, where a computer system interprets the results as images of temperature, wind speed and intensity.

The interferometer is different from others in that it is able to accept light entering over a wide range of angles, which permits it to transmit images rather than just an isolated spot of light at any time.

Only a few moving parts are incorporated: a filter wheel to select the molecular emission to be studied, and a precise scanning mirror capable of setting its position repeatedly to within one-hundredth of a wavelength of light.

Design was complicated by the fact that the glass had to be maintained to within a few hundreths of a degree C in order to produce measurements with the accuracy required. Mechanical stresses can also distort the optical properties of the glass, which had to be mounted in a stain-free, temperature-controlled enclosure. In 1985, WAMDII passed tests for vibration, outgassing, temperature stability and operation in a vacuum. Since then, the engineering prototype has been used for field measurements of the aurora with great success.

Incidently, the UARS satellite to be launched from STS-54 later in 1991 also carries a WAMDII-like instrument, this time called WINDII (for WIND Imaging Interferometer). It is a second-generation WAMDII intended for long-term observation of upper atmospheric winds. Because it will be part of a longer mission, the competition aboard the satellite for power and communication time will limit WINDII to less voluminous information transfers. WINDII is a joint Canadian-French project aboard the American UARS satellite.

S.F. JOHNSON
Hampshire, England

Mir Translation

Sir, Letters from Simon Barnsley (***Spaceflight***, September 1987, p.345) and H.J.P. Arnold (***Spaceflight***, February 1988, p.73) discuss the different possible translations into English of Mir. It may be of interest to them that in the Soviet book "Salyut-Mir" [1], the translation is given as 'peace'.

MARC D. RAYMAN
California, USA

Reference

1 Salyut Mir", Novosti Press Agency Publishing House, Moscow, 1987

Shuttle Needle

Sir, On a recent visit to the National Needle Museum at Redditch, West Midlands – a town world famous for its needle industry the last thing that I expected to find was any connection with space flight and yet, there is was.

On July 5, 1983, The Queen officially opened the Forge Mill and Needle Museum and to commenorate this event she was presented with a perspex block containing two needles and a certificate.

One of the needles was a very fine surgical, semi-circular needle that was used by Rockwell International at their Space Shuttle assembly plant at Palmdale, California. This needle, supplied by a Redditch company, Shrimpton and Fletcher, is used by Rockwell operators to hand sew silica cloth thermal barriers and gap fillers that are used in such areas as landing gear doors, hatches and control surfaces on the NASA Space Shuttle vehicle. Replicas of both the perspex block and needles, and the certificate, are on display at the National Needle Museum.

I wonder what else may be discovered in unlikely situations! Have other readers similar "finds"?

PHIL J. PARKER
Staffs, UK

CORRESPONDENCE

Challenger SRB's

Sir, It puzzles me greatly why, when the Challenger Shuttle 'blew up', did the badly damaged SRB (and the good one) carry on flying. When one imagines the amount of force involved I find it hard to believe that the shock wave did not cause the break up of the SRB. I have read many reports about the explosion and I understand that it was partly the aerodynamic pressure that caused the Shuttle to break up: but surely with part of the circumference of the SRB destroyed and the apparent swinging action once the lower connection points had been broken, the SRBs would have blown up as well? The only conclusion I can come to is that there may have been some kind of intervention as yet unmentioned.

GREG SMYE-RUMSBY
Bromley, Kent, UK

Tereskhova's Zond Mission

Sir, Concerning Lucien van den Abeelen's question as to why Valentina Tereskhova is seen in a photo wearing a Voskhod or early Soyuz flight suit: Tereskohva did leave the space programmme soon after her flight, but, during a visit to Havana, Cuba, in a speech to the Cubans she said: "The Moon team has already been picked. Major Gagarin is head of it, and I am on it."

Although statements made on the Moon team by Vitaly Serastyanov in 1981 do not mention either Gagarin or Tereskhova as members, it seems a possibilty that this photo shows Tereskhova training for a Zond mission. This possible flight never happened when the Zond programme was abandoned after the Americans put men on the Moon.

FRANCIS FRENCH
Altringham, Cheshire, UK

Weightless Experience

Sir, I was interested to read about the brief weightless experiences of Curtis Peebles in his article "Flying the Weightless Profile" (***Spaceflight***, June 1988, p.248).

In my student days, I was an active member of the Queen's University Gliding Club and built up a total of over 50 solo hours between 1975 and 1978. During that period I experienced G-forces ranging from minus 2 to plus 5 in various aerobatic manoeuvres, mainly in a Blanik twin-seater and a Skylark 3F single-seater.

Mr. Peebles points out that the parabolic flight flown by NASA's KC-135 "Vomit Comet" can be reproduced in a light aircraft. The manoeuvre can also be performed in a glider. In fact, in the absence of engine noise and vibration, I suspect that the experience of brief weightlessness in a glider is even more spectacular. Furthermore, as there is no engine to stall, the manoeuvre is probably safer than in a powered aircraft.

On June 30, 1978, while on holiday, I flew a K-8 single seater glider over Portmoak in Scotland. After a winch launch, I climbed in thermals to a safe aerobatic height of 3,000 feet. I then dived steeply, reaching a peak speed of 85 knots (100 mph) before pulling up into a steep climb. During the transition from dive to climb I would have experienced approximately "2½G" (and I must say that I always found high G-forces to be not unpleasant!). At the top of the parabolic arc I could feel my weight apparently disappearing entirely, and a pair of sunglasses which I had placed on my lap rose into the air and floated freely in front of my face.

I doubt whether the weightless phase of the manoeuvre lasted more than two or three seconds, but it seemed longer and the image of the gravity-defying sunglasses remains with me ten years later.

If the same manoeuvre is performed incorrectly (with the stick being pushed forward too hard while the glider is still climbing) the result is the almost invariably unpleasant "negative G" which causes all the dirt and grit on the floor of the glider to "fall" rapidly upwards against the canopy and into the pilot's eyes! This is when the odd missing coin can be a real nuisance, and I am reminded of a pair of missing scissors on Apollo 17, and the concern about what they might have done, unsecured, during the high-G re-entry into the atmosphere.

One further word of warning to glider pilots aspiring to be astronauts: a powered aircraft can repeat the manoeuvre as long as the fuel lasts and the pilot's lunch stays down. A glider squanders a lot of height, especially in the dive phase, so the number of attempts in one flight may be small. It is, however, well worth trying.

GEOFFREY BOWMAN
Belfast, UK

Soviet Orbital Module

Sir, I was interested to read the comment by M.M. Hughes in your last issue concerning the continued use of the orbital module in the Soyuz programme. The Soyuz TM is specifically a space station shuttle and not an extended orbital experimentation spacecraft.

Why should the orbital module still be used without exception? Firstly, the orbital module can deliver a vast selection of new equipment, mail, new supplies etc to the Mir Space Station. Secondly the Soviet production line is geared to build the same spacecraft over and over again (the Cosinar/Vostok spacecraft is a good example).

Thirdly, all the docking and navigation equipment is in place and without the orbital module a whole new re-design would have to be undertaken.

Basically the reason is – economics – it proves more useful to keep than a drawback.

GREG SMYE-RUMSBY
Bromley, Kent, UK

More Room

Sir, The letter from M.M. Hughes (***Spaceflight***, June 1988, p.257) raises an interesting point. Why have the Soviets retained the orbital module on the Soyuz when used as a ferry craft?

It made me think back a few years to a comment made by a cosmonaut who said: "When we cast off the Progress vehicle we lose a "room of the cosmic house." Which is of course one reason for the prolonged dockings of Progress vehicles to Soviet space stations.

I feel the situation is the same with the Soyuz orbital module. It serves as a "room of the cosmic house" for storage etc. And of course such a big design change as proposed by Mr. Hughes goes against the Soviet policy which in effect says: "If it is not broken do not fix it."

W.J. WOOD
Hemel Hempstead, UK

Satellite Longitude

Sir, In the mad March days we sought those elusive Frenchies everywhere and found Telecom 1C above 5 degrees west longitude, not east as listed in *Satellite Digest – 213* of the June 1988 issue of ***Spaceflight***.

BRIAN N. LEE
Wokingham, UK

CORRESPONDENCE

Baffling Statement by UK Minister

Sir, Now that the initial furore over the Government's attitude to space has died down Ministers are, no doubt, regarding this as another hurdle overcome. Indeed, their attitude can be summed up by a remark attributed to Kenneth Clarke recently saying "Space is last year's news".

How anyone in their right minds could make such a statement baffles belief. Indeed, it appears to have prompted Sir Geoffrey Pattie, former Information Technology Minister, to comment: "It is quite clear to me that the Government has taken, one hopes temporarily, leave of its senses."

If such lack of vision is to be the calibre of the leadership, Government posturing on the foreign stage will do little to fill the gaping void in our well-being which is certain to emerge one day.

What we ought to be doing now is create a direct liaison with the Americans on the space station, since the road through ESA will undoubtedly be blocked. We could try introducing users e.g. from experimental groups or the private sector generally.

There ought to be some concern about the Polar Platform, also. It seems to be becoming even less relevant to the space station than before and emerging as an ordinary satellite, no more than a successor to ERS-1.

As the colossal UK space run-down ends, what shape will our country be in when the bugle finally calls? How shall we retrieve the mistakes of the past when it will take us two or three years just to reassemble the destroyed capacity?

Our children will all be looking for jobs, opportunities, new visions, excellent standards of living and a place in the sun.

All they will get will be: "Sorry, chum – try somewhere else."

P.R. FRESHWATER
Henley-On-Thames, Oxon

Who's Left in the Cosmonaut Corps?

Sir, A recent article (Shatalov interview, *TRUD*, April 12, 1988) discusses the current disposition of veteran cosmonauts. It reveals that at Zvyozdniy Gorodok ("Starry Town", often mis-translated as "Star City") staff work has absorbed Klimuk, Dzhanibekov, Malyshev, Glazkov, plus Zudov, and several older cosmonauts such as Popivich and Volynov; health retirement has removed Zholobov and Sarafanov; the ambiguous phrase "employed elsewhere" is used for Kovalenok, Kizim, Popov, Vasyutin, and all older folks.

Who is left and what does this severe RIF (reduction in force) imply for future operations?

The only veteran pilot cosmonauts still "active" all have flight assignments:

Vladimir Titov (41) in flight until December,
available for one more visiting flight in 1990-1 (?).
Vladimir Lyakhov (47) Soyuz TM-5/6, June/August 1988,
to retire post mission.
Anatoliy Berezovoy (46) b/u on Soyuz TM-6, August 1988,
at least one more mission, short visit, 1989 (?).
Alexander Volkov (40) commander of next long expedition,
maybe another flight, a short visit, afterwards.
Alexander Viktorenko (42) b/u to Volkov on next long mission, to command subsequent long mission, 1990 (?).
Anatoliy Solovyov (40) commander of Soyuz TM-5, Bulgarian mission, then backup to Viktorenko, 1990, and command long mission, 1991 (?).
Yuri Romanenko (44) post-mission activities, probably will not fly again.

No other veteran pilot-cosmonauts appear available for flight assignments. But at expected flight rates, those remaining may be enough, since only one long mission commander is needed per year, and two or three short mission commanders, with a flow of:

a. first mission as visit CDR;
b. second mission as long CDR;
c. third mission (if any) as complex visit CDR;
d. leave corps.

This requires a "production rate" of one new pilot-cosmonaut per year, or a class of 8-10 men every four years (assuming 50 per cent training attrition). There may be as few as 25 pilot-cosmonauts in the entire Soviet cosmonaut cadre flow.

Note that this (one new CDR per year) has in fact been the average production rate for the past 15 years or so (not counting the anomalous FE CDRs in 1979-1980):

1974: Sarafanov
1975: Gubarev
1976: Zudov
1977: Gorbatko, Kovalenok, Romanenko
1978: Dzhanibekov
1979: Lyakhov
1980: Popov, Malyshev, Kizim
1981: None
1982: Berezovoy
1983: Titov
1984: None
1985: Vasyutin
1986: None
1987: Viktorenko
1988: Solovyov, Volkov
... or 17 new CDRs over 15 years.

How about flight engineers? They are not resident at ZG and there seems to be a pool (at the spacecraft design bureau and at Mission Control) from which requirements may be activated.

Almost certainly off flight status are: Rukavishnikov, Aksyonov, Kubasov, Makarov, Grechko, Strekalov, Rozhdestvenskiy, Solovyov, and Savinykh (post-flight).

Possibly available for another mission: Ivanchenkov (48), Alexandrov (45), Lebedev (46) and Serebrov (44).

Certainly available for another mission: Laveikin (37), Manarov (37), plus new names Zaytesev (30) and Kaleri (31) – class of 1980-2?? Since the FE training flow is shorter, fewer need to be in the pipeline, so a total of 15 to 20 would be sufficient.

Specialised shuttle training ("about five or six", according to Dzhanibekov in May 1988): Volk (51), Levchenko (47), Shchukin (41), plus one or two of their associates.

As to scientists, three doctors have now been seen in training/flight in 1983-8: Atkov, Polyakov, Arzamazov. Several others are possible.

How many women are in the corps? Shatalov (May 1988) and Leonov (November 1987) were emphatic that there were no women in training and probably would not be for the rest of the century.

In summary: there are probably between 45 and 55 in total. This is consistent with Soviet responses that there were "about 50 cosmonauts of all types. It is far below the number of American shuttle astronauts (almost 100) and payload specialists in preparation (30-40 more).

This low staffing level of veterans strongly suggests that the Soviets do not plan any significant increase in flight rate for at least five years, maybe longer. The new men flying now may be enough to provide the experienced cadre for Mir 2 large space station operations in the late 1990's.

JAMES E. OBERG
Texas, USA

CORRESPONDENCE

V-2 Rocket on Display

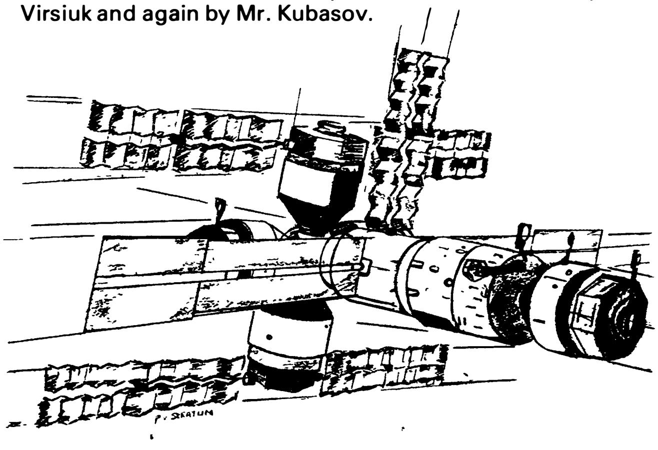
Sir, A few months ago ***Spaceflight*** carried a discussion of remaining V-2 rockets. If anyone is keeping an inventory of the matter there is an existing example of the V-2 at Marshall Space Flight Center in Huntsville, Alabama, USA. It is on display along with a Redstone, Jupiter-C, Jupiter, Saturn 1-B, and an Aerobee.

Dr. ROWLAND E. BURNS
Alabama, USA

Mir Power Supply

Sir, Further information on Mir's power supply is gradually coming in. Meanwhile, it has become clear that Mir's third solar panel, which was added during an EVA, has solved Kvant's problems as far as the power supply is concerned. It is hard to believe that the Russian technicians were not aware of the power shortage. They must have known that the two fixed solar panels of Mir would not be sufficient for Kvant. Why then didn't the Russians equip Mir with a third "fixed" panel? Maybe because of the weight?

Questions directed at Russian technicians and Glavkosmos officials remain unanswered. Now it is becoming more and more apparent that the installation of the third solar panel served as a kind of training for the extension of the station's power supply once the four modules are joined. I have arrived at this conclusion following an interview with cosmonaut/constructor Valery Kubasov in May 1988. After Jean-Loup Chretien had told me at Le Bourget in 1987 that the four modules would be Kvant shaped, this was affirmed by Mr. Virsiuk and again by Mr. Kubasov.



Mr. Kubasov told us that the solar panels can be fixed to Kvant, and the same goes for the next modules. Because these four modules will be launched by a Proton rocket, there will be no room for "fixed" panels on the outer skin. Therefore the panels of the new modules will have to be fixed from the outside by means of an EVA.

At the ESA meeting in Strasbourg earlier this year I saw that this is being extensively practised. CNES showed a video tape of Chretien's training programme in which he was working with fake panels during a zero/G dry training. Can we draw any conclusions from this for his November flight?

An optimum use of solar panels (see accompanying drawing) could cause a problem. The station would have to take up a different position within its orbit. The problem which could arise is that the parts which have to be aimed at the Earth could lose their position, and this could also happen to the parts which are used for astronomical observations, particularly the Dutch telescope aboard Kvant. Experiments with these are not going according to plan. The slightest movement caused by a cosmonaut, for instance, will move the whole configuration in such a way that this will adversely affect the quality of photographs taken by this telescope. We can expect activities around the telescope in the near future.

PHILIPP VAN STRATUM
The Netherlands

Number of People in Orbit

Sir, Moments ago I successfully and finally solved the mystery of my counting of the number of people in orbit. A good friend of mine, Dr. Richard Binzel from Tucson, sent me a poster published by the Smithsonian National Air and Space Museum which shows all of the 'spacenauts' until the end of 1987. Indeed, as your reader, Mike Kitchener, has pointed out (***Spaceflight***, November 1987, p.368), I was one out in the counting. This was due to a 'Gibson' syndrome.

I failed to realise the independent identity of Robert Gibson, and had added his recent shuttle flight to the one performed by Edward Gibson on Skylab. With this solution of the mystery, I am very glad to announce that my lists are in good order, and that Laveikin was the 200th person to orbit.

YARON SHEFFER
Astronomy Dept.
Univ. of Texas, USA

Alternative Space Station

Sir, I believe the American plan for an international space station is a bad one and that it will probably end up being cancelled before it even flies. Between now and the time the space station is built, the US space shuttle is expected to perform over 100 flights. On every flight both the shuttle and the space station programme will be 'on the line'. One more disaster and both programmes are dead. There are no back-up space station modules and there is no back-up to the shuttle.

Instead, why not just build several, 100 ton, complete space stations and launch them on unmanned heavy boosters?

These stations should be capable of either being permanently manned or able to operate in a man-tended mode. Each of the space groups – America, Japan, Western Europe – could then have their own space station. Each group could use its own launch vehicles, both manned and unmanned, to service their own stations, and the unmanned heavy booster and the shuttle could be contracted to bring up bulk supplies and bring down heavy cargoes.

Several, separate space stations would solve a number of problems:

1. Reduce the risk of a launch failure halting the space station programme.
2. If a station fails while in orbit, the remaining partners are not out of the space station business.
3. There would no longer be a conflict over the American military using the space station.

On the technical side, users would get much more volume and weight for their money. The dimensions of the currently planned space station modules are 4.25 by 11.5 metres, for a volume of 165 cubic metres. A large, self contained space station might be 8.4 by 20 metres, for a volume of 1100 cubic metres; the equivalent of almost seven small modules (8.4 metres is the diameter of the Shuttle external tank).

Each single space station would be considerably cheaper than a multi-module complex – mass production techniques could be used in making them. Certainly one heavy booster launch would be less expensive than the 20 shuttle launches needed for the current station plans.

Safety would also be enhanced, since there would be less outside connection points that could rupture, and, with the larger volume available, massive amounts of supplies and spare parts could be kept on board.

Some astronauts have already complained about the large number of space walks necessary to construct the currently conceived space station. Most of these would be eliminated.

A much greater variety of experiments could be performed on the many large stations than on the one, small, multi-module complex.

I would also suggest that these space stations be placed at 57 degrees inclination, rather than 28 degrees. The reasons for this are:

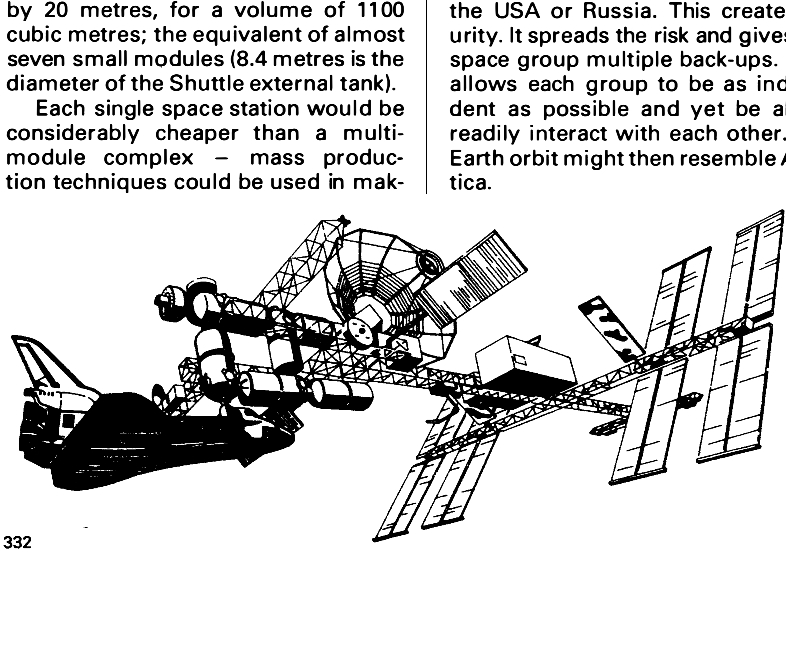
1. Better Earth sensing. For example, most of Europe would be covered. This might negate the need for the Polar Platforms.

2. It is the highest inclination orbit possible from Cape Canaveral.

3. It creates the opportunity for closer cooperation with the Soviet space programme, since it is very difficult for them to reach the 28 degree inclination.

At 57 degrees all of the space faring nations would be able to access each other's space stations. If standards on station size, docking ports and atmosphere could be worked out, the various space groups would be able to engage in mutual space rescue, as well as regular exchange visits.

Shuttle and heavy launch services might then be contracted either from the USA or Russia. This creates security. It spreads the risk and gives each space group multiple back-ups. It also allows each group to be as independent as possible and yet be able to readily interact with each other. Low-Earth orbit might then resemble Antactica.



On the negative side, the high inclination orbit would mean a five to ten per cent loss in payload mass. I think, however, that the greater remote sensing capabilities and the technical benefits from greater international cooperation would offset these losses.

A big objection from NASA would be that 57 degrees would be a better inclination for their reuseable, lox/hydrogen Orbital Transfer Vehicle (OTV). However, the chemical OTV looks at present like another shuttle programme. The cost of placing a payload into higher orbit is likely to increase dramatically with an OTV, leaving everyone looking for the old expendable upper stages. In any case, because of the hazard from all that high energy fuel, OTVs should be kept away from the space station.

Each of the large space stations would probably cost more than a single small module hooked into a multi-module complex. However, with little chance of the multi-module station actually being built the savings become irrelevant.

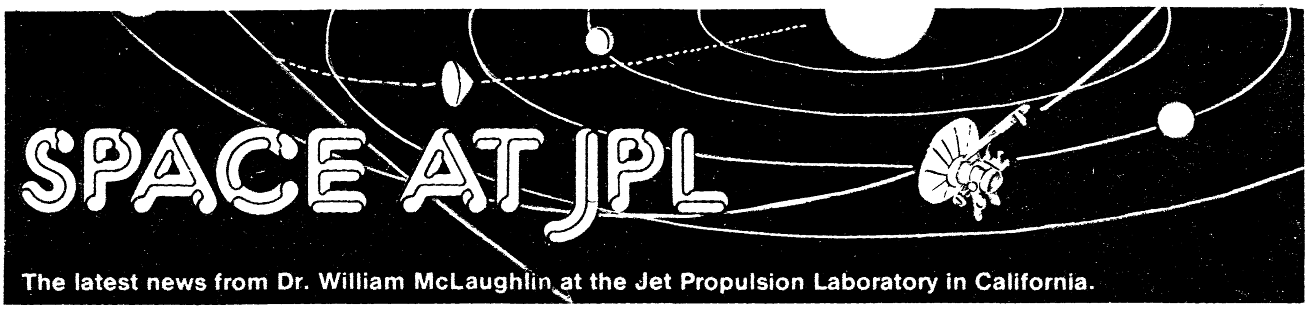
The original reason for building a space station out of small modules, rather than using a single large one, was to save money. The space shuttle was to reduce the cost of space transport to only a fraction charged for the Saturn 5. It has not worked out that way. It costs much more to place freight in orbit with the shuttle than it would have with the Saturn 5. Consequently, there is no reason to build the space station out of small modules.

If America really wants to be a space leader, on par with the Soviet Union during the space station era, it must have more than just the shuttle and Titans as its larger launch systems. It has to build a heavy 100 ton payload booster. It also needs a new, man-rated, all-liquid fuel, medium-lift launcher. This could be used to launch a manned capsule to the space station, and also to supplement and act as a back-up to the shuttle and Titans. This launcher should be kept separate from all shuttle facilities.

The American launch systems are too vulnerable and too dependent on solid fuels at the present time. Consider the recent loss of the solid fuel plant in Nevada.

The new, all-liquid medium launcher could begin the weaning away process from solid fuels, or at least serve as a back-up. With the heavy launcher, the all-liquid medium launcher, and the capsule, America would get back some of the capability it had before it foolishly threw away its Saturn launchers and Apollo capsules.

GEOFFREY BESLITY
New York, USA



Computers and Language

Boris Katz is a Research Scientist at the Artificial Intelligence (AI) Laboratory of the Massachusetts Institute of Technology (MIT). He is engaged in linguistic research with the goal of installing natural-language capabilities in computers: language recognition and language generation through machine actions. As part of this programme he has been collaborating with engineers at JPL in order to apply his automated methods to problems of space flight (for a technical summary, see the November 1987 issue of *JBIS*).

My visit to the AI Lab, located in Cambridge, Massachusetts, was designed to continue our interaction with respect to machine processing of natural languages; a bonus resulted from the opportunity to talk with researchers in robotics – see the following piece on "gnat robots". Cambridge, like its older friend in East Anglia, is a wonderful place. It is the home of MIT and Harvard, hosts some fine bookshops, supports numerous cultural activities, and has roots deep in American history. From a tramp around Walden Pond, celebrated by Thoreau, to modern laboratories at MIT, Boris Katz and I took advantage of this venue to look into some future paths for language development.

Trained as a mathematician at Moscow University, Katz first investigated the relation between language and machines by devising algorithmic methods to produce standard mathematical formulations of "word problems", those mathematical conundrums that have been the baine of generations of Students. He followed this introductory work by applying techniques of machine language generation to poetry The vocabulary of the Russian poet Osip Mandelshtam (1891-c.1940) was put at the disposal of a language generator, constrained by some elements of versification and Russian grammar, and a new set of poems was output. The verses were sufficiently authentic to startle students of literature upon recitation

A more formal natural language system has been designed by Katz over the past ten years. The system is called START (Syntactic Analysis using Reversible Transformations) and consists of two modules. The understanding module operates on English text and reduces it to a knowledge base for storage in computer memory. The generating module utilises the knowledge base to produce English sentences.

The overall approach for START is to rely as much as possible upon syntactic analysis in order to give the system broad applicability. "Syntax" is the system of rules of grammar and usage that organises a language. For example, to split or to not split an infinitive is a syntactic decision. "Semantics" is not concerned with form but with meaning: to what object a set of words refers Thus, pure mathematics is viewed by most as a syntactic discipline while the natural sciences have large semantic components with their frequent reference to objects and their properties. In applying START to a new field, such as spacecraft operations, specialised semantic information need only be added to the syntactic base, much in the same way as humans acquire knowledge of a discipline

The fundamental syntactic unit in START is the T-expression ("T" for "ternary"), which reflects the basic tripartite structure of the English language; subject-verb-object The sentence "Gabriella might buy some stickers" would be reduced by START to the T-expression "Gabriella-buy-stickers" for insertion in the knowledge base The remaining details of the sentence (adverbs, tense, auxiliaries, etc.) are recorded in an ancillary structure, the history, which is also placed in the knowledge base

More complicated sentences can be dealt with by successive extraction of T-expressions. Thus, "Jessica wanted the computer to print the message for Miriam" becomes the T-expression "Jessica -want-it" with "it" defined by a second T-expression One can also acquire the semantic information that Jessica, Gabriella, and Miriam are the linguist's three daughters and feature prominently in his examples.

The language generation module within START trades upon the knowledge base built up by the understanding module. The principles are illustrated by looking at an example wherein START has been asked a question. "For whom did Jessica want the printout of the computer?" This would be rearranged into the form of a T-expression: Jessica-want-printout/for whom Then, upon searching through previous entries in the knowledge base, START would find the answer (refer to the preceding paragraph)

Language situations that are treated effortlessly by humans can puzzle a machine unless it is explicity instructed as to how to deal with the situation Prepositions pose particular problems. We know that if "Miriam presented a gift to Gabriella", then "Miriam presented Gabriella with a gift". START is told this fact (in more generic form, with variables in place of the three nouns) as a rule to apply in utilising its knowledge base. In fact, a whole set of "if-then" rules, called S-rules ("S" standing jointly for syntax and semantics), is included within START and can be easily modified to meet the specific needs of an application. Thus, not only the general syntactic/semantic aspects of English can be handled but also idiomatic usage can be accommodated through the utilisation of S-rules

The S-rules can operate in "forward" or "backward" directions when stocking the knowledge base with information or extracting it in response to a question. This reversibility is noted in the "R" of "START".

The burden of employing specialised rules is eased by the existence, within the English language, of classes of verbs which exhibit similar behaviour. Hence, "Jessica ate a pear" implies that Jessica ate, but "Miriam brushed the cat" does not imply that Miriam brushed (herself) More generally, "eat" belongs to the class of verbs specifying occupations (eat, drink, hunt, plough, etc.) while "brush" is a member of the class of verbs that denote grooming activities (brush, bathe, dress, comb, etc).

A major component which Katz has incorporated in START is the Lexicon. Just as each T-expression, the distillation of a sentence which START has read, is supplemented in the knowledge base by 'history' – details – the words in the vocabulary of START are stored in the Lexicon along with detailed information for each entry Detailed information includes class membership for verbs (e g., occupational or grooming), gender, number, part of speech, etc. Similar to the case of the set of S-rules, augmentation of the Lexicon is a straightforward process, enhancing the adaptability of START

Before the natural-language capability could be brought into service for flight projects at JPL, it will be necessary to demonstrate its reliability, linguistic breadth, and ability to cope with a large volume of data. Katz has been working with JPL engineers, led by Robert N. Brooks, to test a prototype adaptation of START using realistic data from certain flight projects

Two primary kinds of applications are envisaged: (1) creation and interrogation of knowledge bases, and (2) simplified control of computer programs The first application has obvious benefits; the second application allows an individual to operate a program without extensive indoctrination in its protocols. If an individual desired to turn on the spacecraft's camera, instead of composing a request consisting of a string of seemingly arbitrary symbols, as is the case at present, the individual could simply say, "turn on the camera at time t".

Both categories would be particularly useful for scientific investigators located at remote sites such as universities. This class of spacecraft user does not generally have detailed knowledge of flight-team procedures and would welcome a higher-level computer language, in this case English.

Two important human faculties are vision and language. The use of computers for graphics and visualisation is based upon the former faculty and has proved to be a great success. The importance of language underwrites the value of efforts to bring this set of skills to the machine.

Gnat Robots

Robots are typically thought of as rather large objects that, when they are not fixed in place, lumber about in pursuit of their goals. Most work in robotics has focused on improving the capabilities of these devices by adding more sophisticated sensors, control systems, locomotors, and manipulators. A promising new direction for robotic evolution has been proposed by researchers at the Artificial Intelligence Laboratory of the Massachusetts Institute of Technology (MIT): a developmental line that might someday lead to simple, cheap robots the size of an insect. The massive parallelism inherent in a large number of "gnat robots" could be expected to facilitate cost-effective solutions to a variety of tasks. Consider, for example, the scouting power of a swarm of gnat robots deployed in a sector in advance of a Mars Rover.

The attempt to produce gnat robots is one aspect of the MIT Mobile Robot Project which is led by Professor Rodney A. Brooks. The objective of the project, established in January 1985, is to build robots that can act autonomously and robustly in a dynamically changing environment. Most current robots flourish in a well calibrated environment while performing repetitive tasks; they do not prosper where conditions are uncertain.

For controlling mobile robots, Brooks has developed an architecture for intelligence that readily lends itself to the addition of new capabilities and exhibits durability under operational stresses (see his paper in the March 1986 *IEEE Journal of Robotics and Automation*). The control system acts as an intermediary between the robot's sensors and actuators. Each level of the multilayed control system is composed of communicating modules and is designed to perform a specific behavioural action. For example, the lowest level might be assigned the function of avoiding objects that attempt to approach the robot, the second might initiate patterns of wandering, the third undertake exploratory actions while wandering, etc.

Most current robots flourish in a well calibrated environment while performing repetitive tasks; they do not prosper where conditions are uncertain.

The label "subsumption architecture" has been applied to describe the fact that a higher-level layer subsumes the functions of lower levels in a coordinated fashion. The scheme is robust because the robot will continue to perform, with reduced capability, even if some higher levels become inoperative. The subsumption architecture differs from the formulation of classical control systems by being based upon task-achieving behaviours (avoidance, wandering, etc.) rather than more rationalistic functions such as modelling, planning, task execution, etc. Brooks has sharply etched the distinction with the aphorism, "planning is just a way of avoiding figuring out what to do next".

The widely held opinion that artificial intelligence (AI) has not lived up to its early promise may, according to Brooks, be partly due to the tendency of many AI researchers to emphasize abstraction in their designs. They solve the intellectualised "AI portion" of a problem and then abandon the enterprise to others to complete.

A prescription for avoiding this malaise is to emphasize task achievement, as built into the subsumption architecture, and to force the robot to function in places not specifically designed for it. "Herbert", put together by Jon Connell and Peter Ning, is an instance of this approach; his goal in life is to wander around the MIT AI Lab and collect soda cans that he finds on desks. It was impressive to watch the upper half of Herbert, assembled on a workbench for testing, detect a soda can placed in front of him and reach out and successfully seize it.

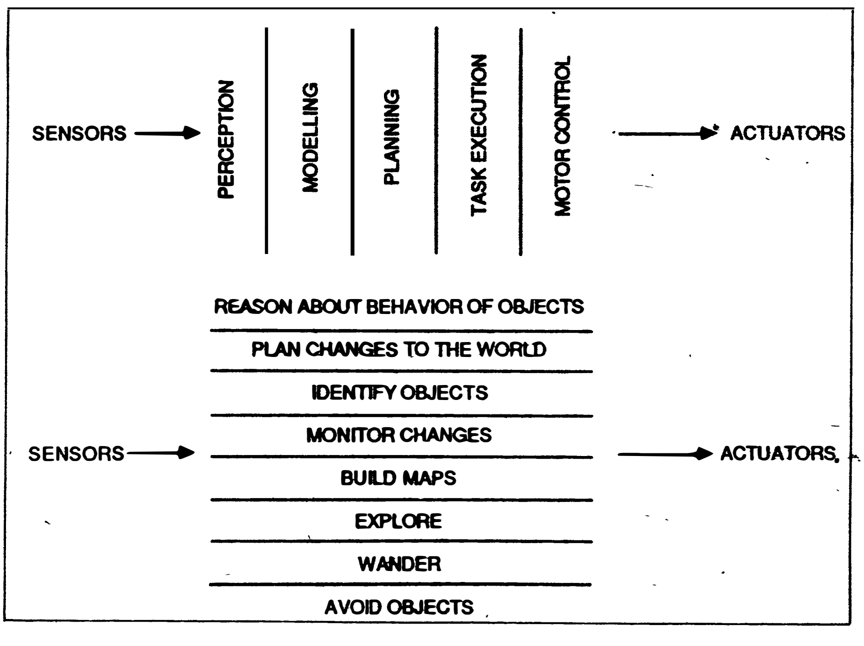
Brooks advocates building artificial insects as a goal for AI and robotics. The simpler capabilities of artificial insects are not only more achievable than those of humans but also could serve a multitude of our needs. Brooks illustrates the concept with a sketch of a robotic vacuum cleaner. There would be a large device to collect dirt, and it would be accompanied by several dirt-collecting artificial insects, each about two inches in length. An insect will wander around the house and have a predilection for corners. Dirt will be pulled out of the carpet, perhaps electrostatically, and stuffed into the insect's stomach. Brooks describes a solution to the problem of coordinated disposal: "What should it do with the dirt? One approach is to have it go to some central location and get rid of the dirt. But that implies extremely good navigation abilities and a detailed model of the house. This is beyond a simple insect. Instead, there will be another layer of control utilising sound sensors. It will listen for the big vacuum cleaner. When it hears it, it will run to the middle of the room and dump its guts all over the floor. Such is the future."

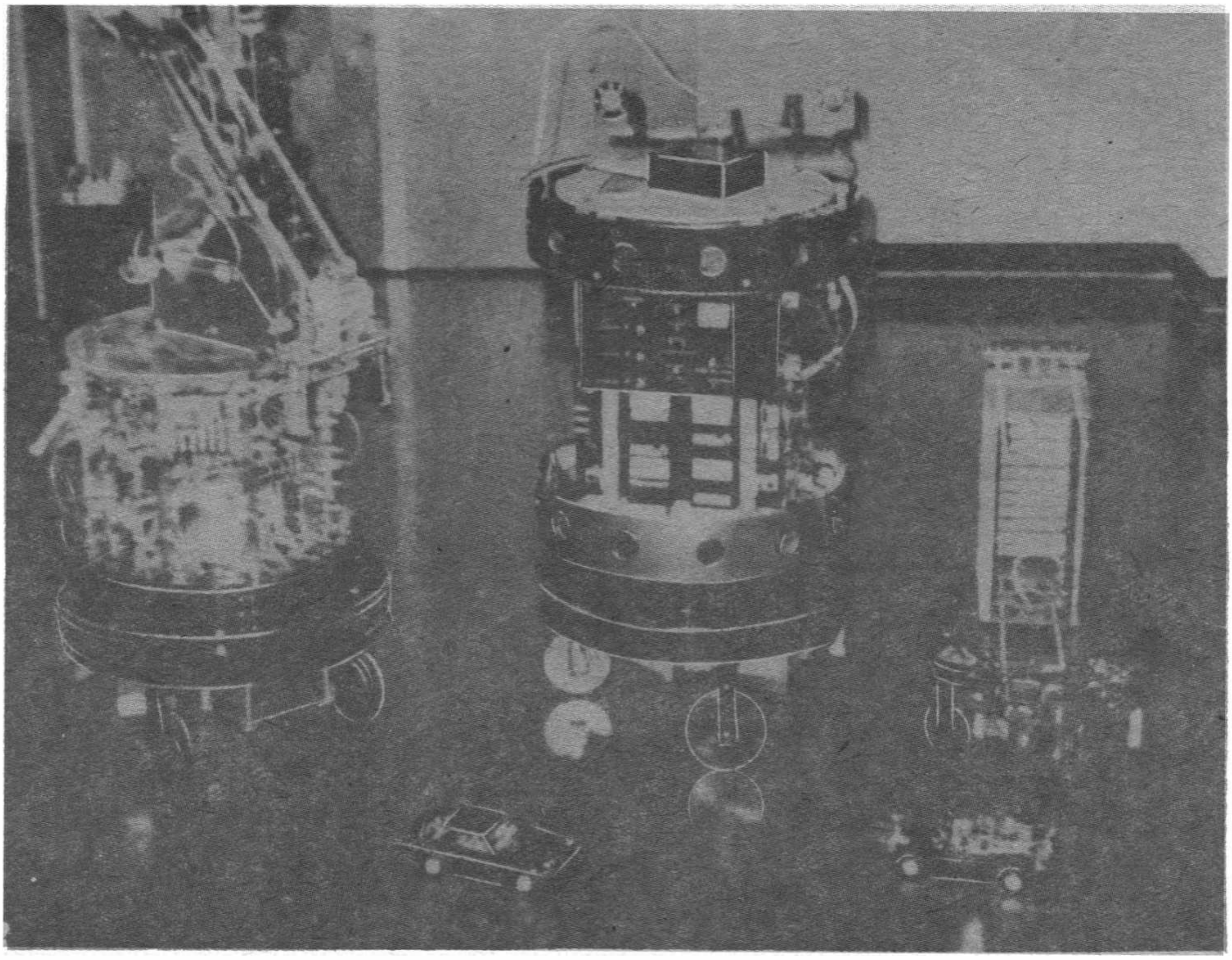
Anita M. Flynn is a Research Scientist in Brooks' Mobile Robot Group. Upon seeing plans for an extremely small motor, of millimeter dimensions, she began to put together the concept of "gnat robots". The gnat robot would push the idea of insect intelligence to its logical conclusion through hyper-miniaturisation.

The principal challenges in this research programme lie in the five areas of microsensors, control systems, actuators, power sources and systems integration (see her article, with an extensive bibliography, in the December 1987 *AI Expert*). Flynn said that while subsystems were not now adequate to support gnat-sized robots, reasonable engineering extrapolations make the idea plausible. For example, efficiencies of solar cells have been increasing as a result of research efforts. These power sources would be well suited for mass production as part of an integrated-circuit package; a tenet of the gnat-robot programme is that economy is necessary for viability.

A gnat robot's actuators could move it through space perhaps by flying, crawling,

Roboticists at the Artificial Intelligence Laboratory of the Massachusetts Institute of Technology have developed a layered architecture for robot control systems (lower half of diagram) which emphasizes task-achieving behaviour. Classical control-system architectures (top half of figure) have concentrated upon representing the world before prescribing actions for the robot. *MIT AI Lab*





In this family photograph, five mobile robots from MIT are shown. From left to right the three larger robots are: Herbert, Allen, and Seymour. Tom and Jerry are in front.
MIT AI Lab

hopping, swimming or rolling Locomotion by flight is attractive but poses difficult problems in microaerodynamics – a regime which is not well understood. Exemplifying the evolutionary strategy of the Mobile Robot Project, Flynn suggests beginning work on miniaturisation of sensors, actuators, and control systems by placing them on a very small lightweight airplane. In this way initial progress could be made toward realising the gnat's subsystem without having to solve, at present, the aerodynamic problems of insect flight.

For example, a rubber-band-powered aircraft, developed by Mark Drela of the MIT Aeronautics and Astronautics Department, is about 10 cm in length and weighs approximately 80 mg, 30 mg of which is accounted for by the rubber band. The motive power is equivalent to 0.4 mw. Micromotors are still under development as are small power sources, but their expected capabilities are within range of the requirements to drive an aircraft of Drela's class.

The imperatives of miniaturisation have led Flynn to consider using components for more than one purpose. Sensors could be doubled up to detect more than one phenomenon. For instance, infrared focal plane arrays could be used not only to detect heat signatures, but also to perform visual obstacle avoidance or motion tracking.

It is not difficult to envisage space applications for gnat robots. Scouting for a planetary rover has been mentioned. Performance of inspection and repair duties onboard spacecraft, particularly for out-of-the-way places, is another application. Atmospheric sampling or subsurface burrowing throughout a widespread network of points could yield synoptic data for focused problems in planetary science. To collect the samples, a variant of Brooks' vacuum-cleaner system might suffice.

The combination of theory with practice is particularly effective and makes the goal of gnat robots seem attainable.

An evolutionary research plan has been developed for the overall Mobile Robot Project as well as for its gnat-robot component.

We have already met Herbert. He was preceded by Allen, in whom was implanted a three-level subsumption architecture via cables from a stationary computer. Allen moved on wheels. He would sit in the center of a room and, using sonar sensors, would attempt to avoid anyone who approached him. The second level of Allen's control system gave him the urge to wander randomly, while avoiding anyone encountered during his travels. The third level of behaviour was exploration; pick a destination and try to go there, steering clear of humans.

Herbert became divorced from reliance on cables and carries his own microprocessors onboard. Consistent with the subsumption architecture, there is no central-planning computer, just the modularised layers. He uses infrared proximity sensors in place of sonar, for faster reaction, and lasers for identification and targeting of his beloved soda cans.

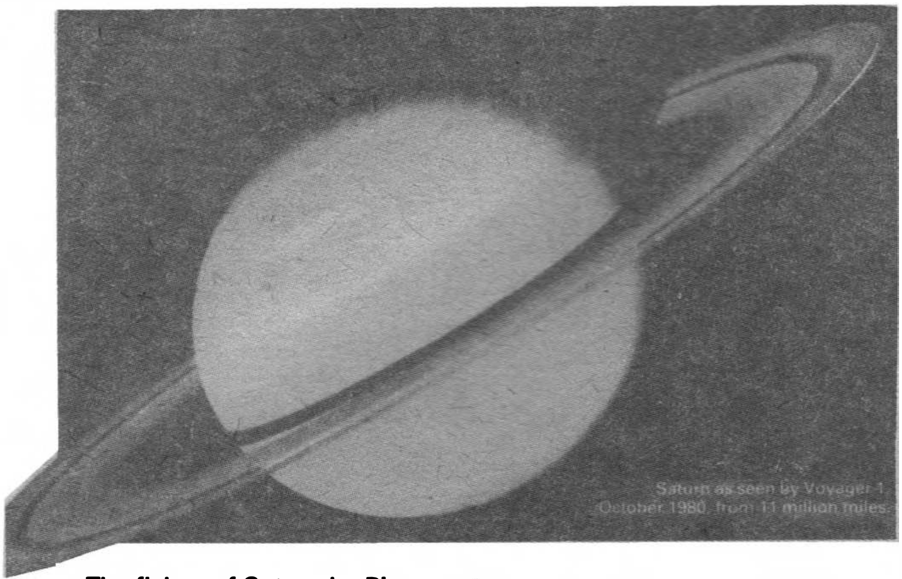
Before completing Herbert, Tom and Jerry, two small toy cars, were modified in order to gain experience with miniaturisation of the control system. The radio controllers in these commercially available products were replaced with a subsumption architecture with three levels: avoid, wander and follow.

Future robots in the evolutionary lineage include: (1) Allenmore, a prototype for a mobile robot with vision, (2) Seymour, about 0.3 m in diameter and 0.5 m tall, who will be a descendant of Allenmore, (3) an autonomous rubber-band-powered aircraft, (4) microrobotic aircraft, and (5) the gnat robot itself.

A spectrum of development programmes for robotic creatures has been emerging in the past few years as engineers attempt to fit their creations into technological niches. In order of decreasing size, we have seen: the JPL telerobot, a macrosized device (see the April 1988 "Space at JPL"); the small spacecraft of James Burke (May 1985); the microspacecraft of Ross Jones (April 1988); gnat robots; and the nanomachines of Eric Drexler (March 1988).

Some of the best work in robotics in the world today is being done in the three floors of the AI Lab in Cambridge, Massachusetts. The combination of theory with practice is particular effective and makes the goal of gnat robots seem attainable.

Cassini Mission to Saturn


Saturn as seen by Voyager 1
October 1980, from 11 million miles.

The flybys of Saturn by Pioneer 11 (1979), Voyager 1 (1980), and Voyager 2 (1981) have revealed a world of great beauty and deep scientific interest. Nowhere is this dual aspect more evident than in the Saturnian system of rings. One of the visual glories of the solar system, the set of rings also represents a natural laboratory for astronomers to test theories that could account for the intricate structures that have been observed. A top NASA scientific priority is to gain approval in the fiscal year 1990 budget to develop and launch in 1996 the Cassini mission to explore the Saturnian system.

The Cassini proposal has been paired with that for a scientifically related mission, Comet Rendezous Asteroid Flyby (CRAF), which would together constitute the first flights for the new Mariner Mark II series of spacecraft; see the April 1987 "Space at JPL" for a brief description of these modularised vehicles. For NASA programmatic reasons, the CRAF mission, which was planned for an October 1994 launch and February 2001 rendezvous with Comet Wild 2 (see the June edition of this column) has been replanned for an April 1995 launch. The spacecraft will rendezvous with Wild 2 in July 2001, 800 days before the closest approach of the comet to the Sun.

Cassini is named after the Italian-French astronomer Giovanni Cassini (1625-1712), who discovered four satellites of Saturn and the major division in the rings which bears his name. The mission plan features deployment of an atmospheric probe into the obscuring mists of Titan, Saturn's largest satellite, and four years of study from orbit of the rings, planet, magnetosphere and satellites.

The Cassini tour of the Saturnian system resembles the Galileo tour of the Jovian system – Galileo is scheduled for an October 1989 launch and December 1995 arrival at Jupiter. – in that both depend upon gravity assists from natural satellites to provide the primary motive force that enables the spacecraft to circulate through most of the scientifically interesting regions of the planetary system. However, the mechanics of the tours differ because Jupiter has more gravitational resources which can be utilised by an orbiting spacecraft: the four large Galilean satellites Io, Europa, Ganymede, and Callisto. Saturn only has one satellite, Titan, sufficiently massive to be of use in Cassini's orbital tour.

The general design of the tour begins with the placement of the Cassini spacecraft in an elliptic orbit about Saturn. The major axis (longest dimension) of the ellipse is then rotated for subsequent orbits in a clockwise direction about the planet, over a period of four years. The rotation is measured with respect to the Saturn-Sun line and is accomplished by about 40 properly aligned encounters with Titan and a few judicious firings of the spacecraft's engine.

Diagrams of this process are called "petal plots" because the cumulative traces of the orbits resemble the petals of a flower. Thus, a "midnight petal" would be composed of one or more orbits whose most distant points from Saturn (apoapses) were in the anti-Sun direction. The virtues of an extensive array of petals are that it allows sampling of the system under differing solar lighting conditions and, more importantly, exploration of various portions of Saturn's magnetosphere.

The magnetosphere is built from interactions between the Saturnian magnetic field and the solar flux of particles ("solar wind") and is inhabited by a population of charged particles. Its outer boundary lies generally in the region of Titan's orbit. But this boundary varies with solar activity and has a hyperextension in the antisolar direction: the magnetotail.

Bearing in mind the clockwise evolution of the petal plot of a tour, driven by application of Titan's gravity, the story of the orbital phase of the Cassini mission is a tale of adventures and actions during this basic circuit.

Dr. Stuart Kerridge, supervisor of JPL's Advanced Projects Group and Mission Design Engineer for Cassini, recounted the major events comprising the planned tour. Kerridge said that in order to take full advantage of scientific observational opportunities one has to think more than a single step ahead in designing the tour: "keep the goals in mind".

Tour-design criteria are drawn with regard to five areas of scientific investigation: the atmosphere of Saturn, rings, magnetosphere, Titan, and smaller icy satellites. The strategy is to treat these categories as having equal value and work priorities within each.

When the spacecraft first enters into the Saturnian system from its interplanetary traverse, it will have an orbit inclined 20 degrees to the planetary equator and a period of revolution of 100 days. The first two encounters with Titan will be used to reduce the inclination and the orbital period. Then, a third encounter with Titan can shift the spacecraft's orbit clockwise, forming a new petal and establishing conditions for the final step in this series of actions: re-establishment of orbital inclination (to 25 degrees) by encounters four and five with Titan.

The purpose of this rather complex sequence of events is to create a geometrical situation that will result in the spacecraft being occulted during an orbit, as seen from Earth, by Saturn and by its rings. Radio waves from the spacecraft, upon passing through the planetary atmosphere and the rings, allow analysis of the structure and composition of these objects. Similar radio-science experiments by Voyager 2 at Uranus were described in the June 1986 "Space at JPL".

Titan encounters six and seven enable the spacecraft to create an orbit suitable for a close encounter with the icy satellite Iapetus. Then the orbit is placed back in the plane of Saturn's equator and clockwise rotation is continued.

The four-year tour for the prime mission of Cassini will contain two encounters with Iapetus, two with the

satellite Enceladus, several ring and atmosphere occultations, and a thorough sampling of the magnetosphere (six months will be spent in a midnight or magnetotail petal).

At the end of the tour, after petals have been created from noon, through dawn, to midnight, and finally to a dusk position, eight months will be spent cranking the orbit up to 83 degrees inclination, by Titan encounters as usual, in order to study Saturn's polar atmosphere and magnetosphere.

Prior to undertaking the tour, Cassini must, of course, get from Earth to Saturn. For the years of 1995, 1996 and 1997 the planet Jupiter happens to lie in a favourable position to provide a gravity assist toward Saturn. This gravity assist, combined with an earlier engine burn and re-encounter with Earth (the so-called ΔV-EGA type trajectory), will bring the Cassini spacecraft to Saturn 6.5 years after launch by a Titan IV/Centaur.

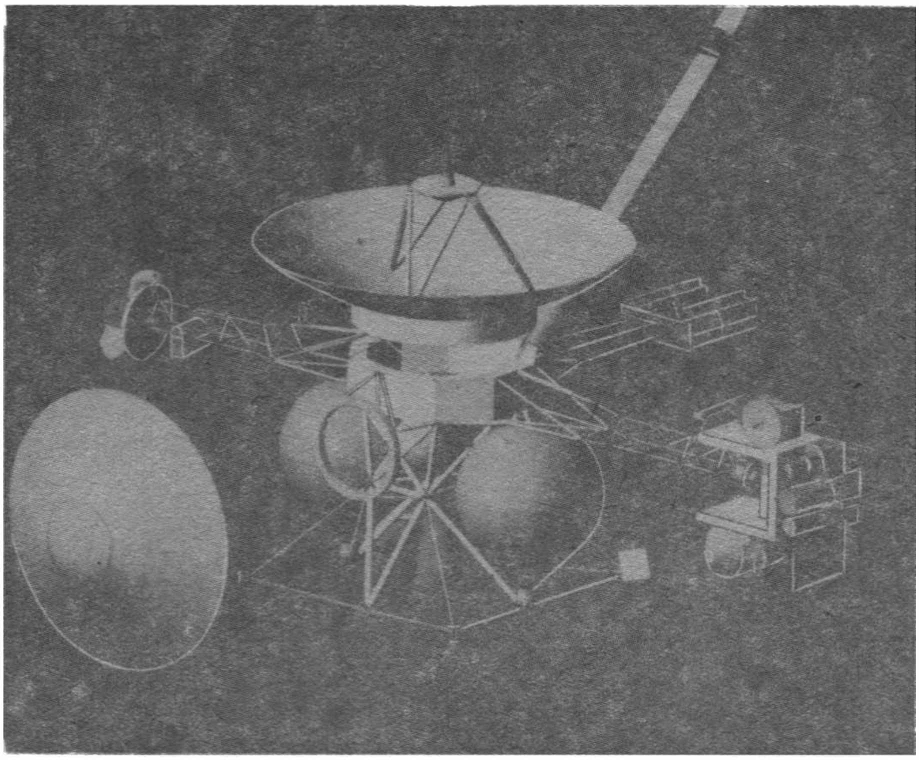
A scientific bonus that accrues from a Jovian gravity assist is the opportunity to conduct a distant Voyager-type study of Jupiter by Cassini as the spacecraft passes the giant planet. Closest approach would be at 52 planetary radii, compared to approximately five radii for Voyager 1 and 10 radii for Voyager 2.

Should the launch be delayed beyond 1997, it would still be feasible to reach Saturn by following the example of Galileo and employing gravity assists from Venus and Earth (twice), making up for the absence of a Jovian kick.

The Titan probe may be built by the European Space Agency; a selection among competing scientific projects will be made by the Agency later this year.

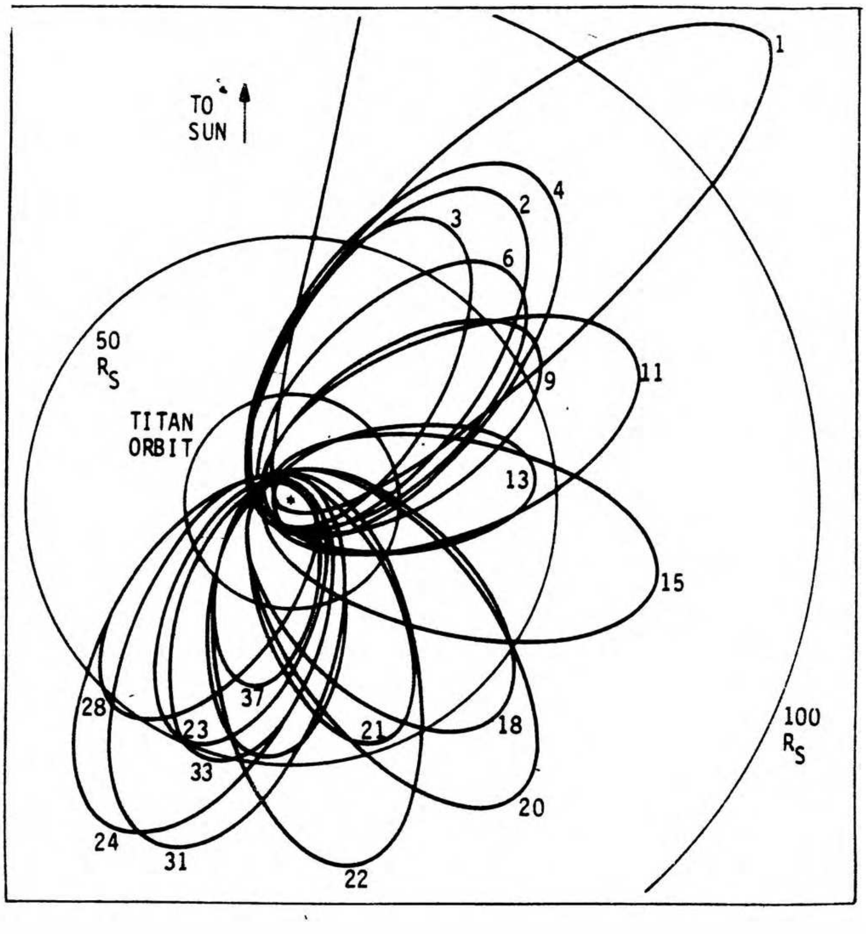
The current plan for deployment of the probe is to release it from the orbiting spacecraft during the first circuit about Saturn. The spin-stabilised probe should have a lifetime of two to three hours after entry into the atmosphere of Titan. Descent through the atmosphere is negotiated by means of a parachute. The Cassini orbiter will serve as a relay to transmit approximately four megabits of data to Earth.

Cosmologists have pushed our knowledge of the early universe back to within a small fraction of a second after the Big Bang. CRAF could continue the theme of origins by investigating the primordial material of a comet – related to the solar nebula from which the Sun and its companions formed. Cassini's contribution to genesis studies would arise, in part, through an analysis of the atmosphere of Titan which has been described as a natural laboratory for studying prebiotic organic processes. The origins of the universe and the solar system and the conditions upon which life is based are three important links between the astronomical universe and "the naked ape".



The proposed Cassini mission to Saturn would utilise a Mariner Mark II spacecraft to orbit the planet for four years and inject a probe into the atmosphere of the satellite Titan. Both orbiter and probe are shown in this computer-generated figure. If approved, a 1996 launch is planned. *NASA/JPL*

A "petal plot" shows orbital traces of the Cassini spacecraft projected on the equatorial plane of Saturn. For clarity, not all of the orbits are shown. The clockwise progression of orbits is obtained by calculated encounters with the large satellite Titan, and measures of scale are provided by the orbit of Titan and Saturnian radii (R_s) circles. *NASA/JPL*



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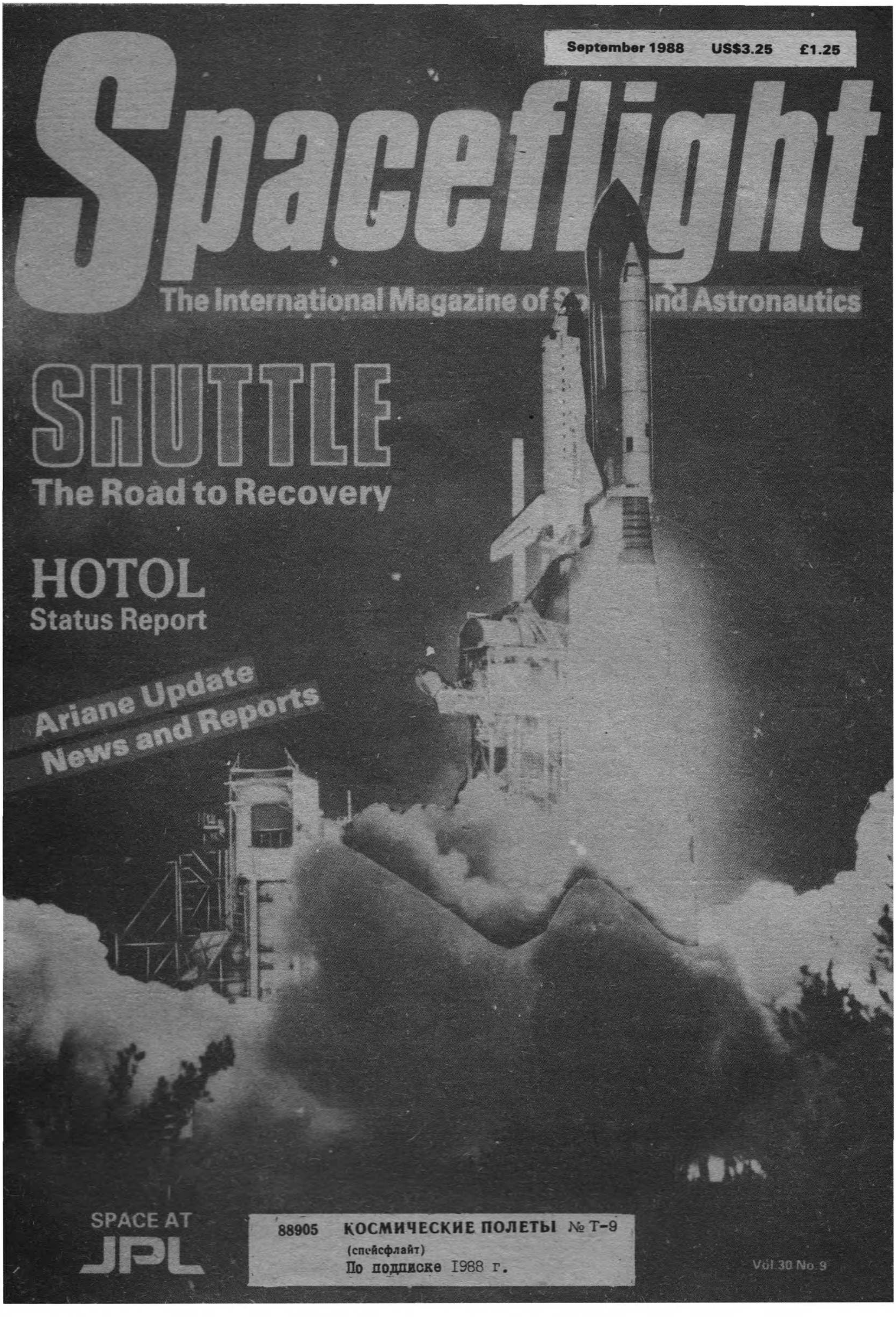

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Spaceflight

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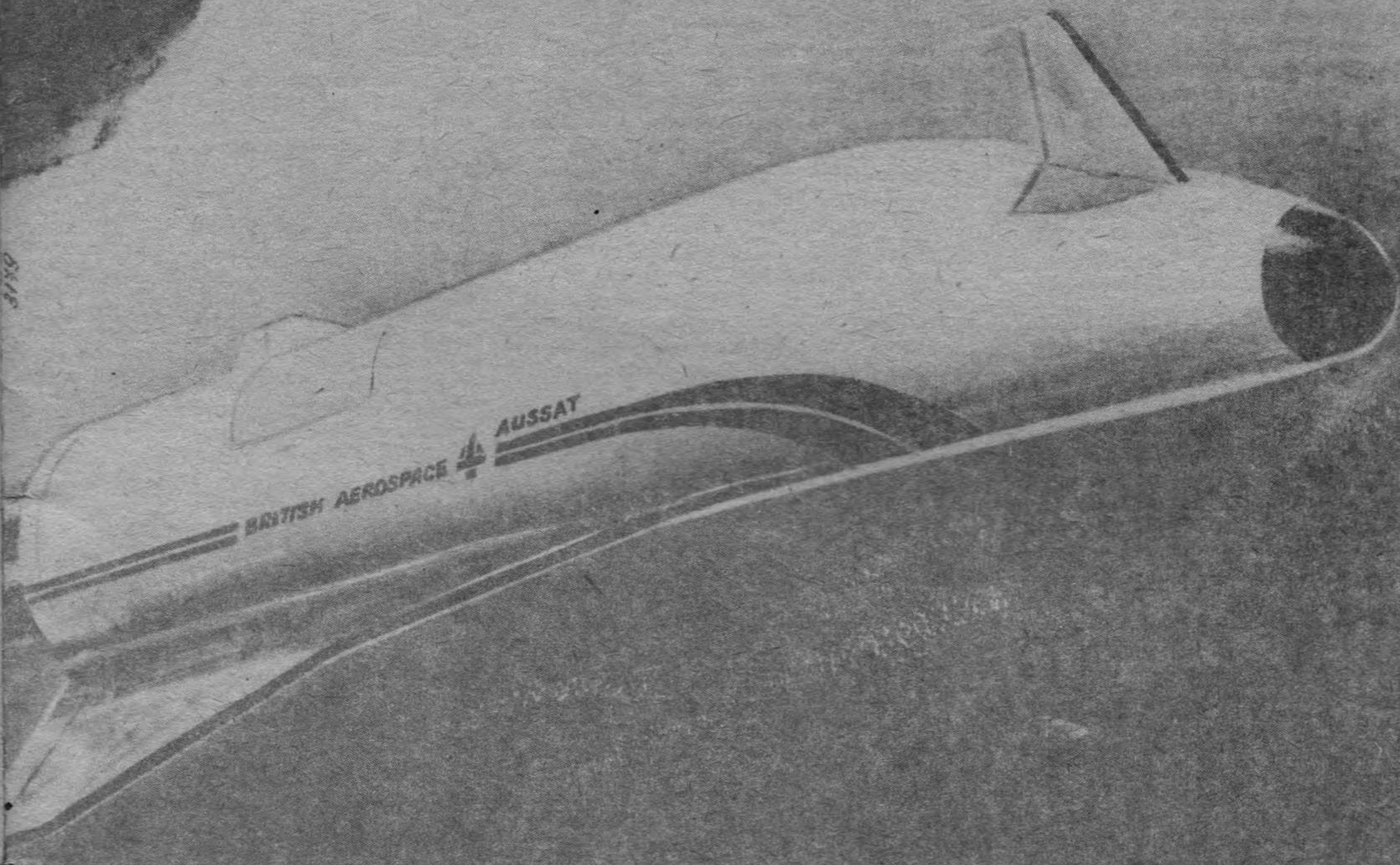
Front Cover: As the long-awaited space shuttle mission STS-26 undergoes final tests, we choose this spectacular picture of a previous Discovery launch. A special feature on Discovery's return to flight begins in this issue on p.351. *NASA*

Artist's impression of Hotol launch carrying Aussat payload from the proposed Cape York international launch site in Queensland, Australia. *British Aerospace*

HOTOL — *Status Report*

by Dr. Robert C. Parkinson

The objective of the Hotol programme from the start has been to provide low cost, reliable launch capacity for the beginning of the 21st Century. Hotol is a British Aerospace/Rolls Royce concept for an unmanned, fully reuseable, single-stage-to-orbit launch vehicle designed to carry 7-10 tonnes of payload into low-Earth orbit at a specific cost in the region of $700/kg.



At the end of 1987 the initial Proof of Concept Study for Hotol had been completed and some additional months of work on optimisation of the configuration carried out.

The Proof of Concept Study has encouraged both British Aerospace and Rolls Royce in the belief that the vehicle concept is achievable, while confirming the absolute optimisation of the propulsion system with the air frame.

The interactions of engine and airframe are considerable. Essentially, it has been necessary to balance drag, mass and propulsive efficiency against operating cost and reliability. The airframe, intake and engine interactions are complex, and as our depth of understanding of the vehicle grows, so does the complexity of the problem that must be continuously balanced.

As a programme initiated by a user group, the top level specification for Hotol remains one of operating cost. The target of achieving a dedicated, seven tonne launch for $5 million is demanding, but setting such an approach sets clear design targets and a basis for judging alternative options.

The programme objective clearly drives the technologies of vehicle and engine design and optimisation, but it also drives the management approach. Although we could have wished for a sounder funding base, it may be that the venture is benefiting from the clear visibility of its operating cost specification. This factor could well be lost in the usual customer specification-break-down tree in which we have all been lost in the past.

What then has been happening? Clearly we have been round the circuit a number of times now on the fundamental questions of mass, drag, performance and controllability.

The results of design studies and wind-tunnel tests against a "reference configuration" are fed into a global computer model which allows us to reoptimise the vehicle with each gain in understanding we achieve. In parallel we have worked through the operational concept of the vehicle in detail to examine the constraints that "real life" imposes, and also to avoid presumptive assumptions which could lead to costly performance demands later. Since there has never been a vehicle quite like this before, even the design rules can at times be a little vague.

The need for an air-breathing engine which can be carried into orbit places a premium not only on high performance (high specific impulse) engines, but also low installed mass engines. The "bare engine" mass and performance of the RB-545 "as supplied by Rolls Royce" has changed little from the start of the study, but size and mass has led us to modify the way in which engine and intake operate together. The trajectory, in-take performance and engine parameters must all be adjusted not only to give the highest performance and lowest mass engine possible, but also to ensure that the engine is used to maximum effectiveness throughout the flight.

The transition from air-breathing to rocket flight remains at Mach 5 by the need to avoid air-intake and engine problems, but the details of the transition assumptions have been refined considerably. There is profit, for example, in allowing the performance of the final phases of the air-breathing flight to be degraded slightly (by flying low and performing a final "pull-up" manoeuvre) in order to achieve better insertion conditions for entry into rocket powered flight.

The configuration continues to change as the design is refined. The aerodynamics of the basic shape has been investigated in five wind tunnels covering all critical flight ranges from sub-sonic speeds to 7.9 km/s. Wind tunnel tests have limitations, but are important to give confidence to computational methods supporting the design.

As a consequence the vehicle aerodynamics have been reshaped for minimum drag in the critical speed range, giving a more continuously tapered shape than hitherto. Base drag is an important area in which good theoretical predictions are difficult to obtain. In addition, the hypersonic wind tunnel tests have given us improved estimates for heating rates and hot-spot areas during re-entry.

The wing shape, thickness and construction have also been worked over to achieve a balance between lift, drag and mass. As with its predecessor, Concorde, effective performance is the consequence of small, careful design optimisation refinements.

The application of new materials to Hotol's structure is again a balance between cost, mass and thermal requirements. If parametric costing can be believed, one kilogramme of mass saved on Hotol's structure is worth nearly $1 million in development, but at the same time the risks and uncertainties involved in developing a vehicle based on the large scale application of laboratory materials must be carefully assessed. We have now been through the structure almost component by component, examining the effects of advanced materials and the materials which have the greatest payoff in overall performance.

The low density of the forward fuselage means that the vehicle experiences lower general surface temperatures than the space shuttle on re-entry, but this is dependent on the temperature limits reached within the structure – in particular in the composite-structure liquid hydrogen tank.

Operational design provides the key to Hotol's cost effectiveness. The vehicle must be designed to be prepared, launched and operated on orbit with the minimum "army on the ground".

At the same time, since the vehicle is re-useable, reliability and protection against loss (safety) issues must be examined carefully. The need to ensure a continuum of abort options from the moment of ignition until insertion into orbit in order to achieve a reliable system (not simply a reliable vehicle) has led to understanding of system constraints which are critical in the overall concept. Other constraints may come from operating Hotol as a pilotless aircraft, limiting flight over areas of population.

For normal on-orbit operations it is intended that the vehicle should have only intermittent communication with the ground. Use of a Data Relay Satellite for more continuous coverage currently looks more expensive as well as limiting vehicle attitude on orbit.

It is expected that Hotol will use advanced computer systems and "AI" both for control systems flight and for fault diagnosis and maintenance planning during turn-around.

One task required of the Hotol Proof of Concept phase was to indentify technology areas which might be critical to the development. From this requirement came an awareness that the next phase of Hotol studies, as well as continuing system studies and optimisation, should include investment in "Enabling Technology". Most of these areas are not engineering "show stoppers", but areas in which early investment is expected to have a major impact on later development. Five key areas have been identified:

- Materials & Structures
- Aerodynamics
- Command & Control
- Sud-System Technology
- Propulsion

In March 1987 British Aerospace, in collaboration with MBB, Aerospatiale and Aeritalia, organised a joint Industry Workshop in Rome to discuss Technology Requirements for a European Advanced Space Transportation System.

There was a surprising degree of unanimity among the delegates about the issues involved, and the need for an early programme of work. Significantly these areas cut across traditional business areas. The technologies involved include Space technologies, but they also – in the areas of aerodynamics and propulsion – include technologies of interest to high speed aircraft and future hypersonic transports.

In addition, the area of command and control involves aspects of Information Technology such as high reliability software and artificial intelligence whose ramifications go well beyond the aerospace industry.

Hotol has emerged from a two-year Proof of Concept Study with its major features intact. The conculsion is that a vehicle of this sort is feasible and economically sound, although it will not be an insignificant development for Europe.

Hotol has emerged from a two-year Proof of Concept study with its major features intact.

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Hotol Funding Shock

On July 25 1988, the then Trade and Industry Minister, Mr. Kenneth Clarke, announced that no further Government funds would be available for the Hotol project.

In a written reply to a Parliamentary Question from Mr. Richard Page MP, Mr. Clarke said:

> "..The scale of funding required to develop Hotol or any similar concept to eventual production would be far too great for the UK to contemplate on a national basis, particularly since only a relatively small number of launch vehicles are likely to be required. I have therefore concluded that further development must take place on the basis of international cooperation. The Government will support efforts by UK companies to find suitable collaborators but will not be providing any further financial support for the foreseeable future. In the meantime I expect the UK, as an ESA member and a participant in earlier Ariane programmes, to have reliable access to ESA launchers which promise to be competitive throughout the 1990's."

The Government's decision on Hotol opens the way for a major part of British space technology to be taken over by any other country whose space industry has the financial backing of its own government. The UK Government's offer to help promote international participation in Hotol is a fallacy and amounts to a 'sell-out' of British technological 'know-how' and expertise.

True international cooperation will prove impossible as the financial resources of British industry without government money would be minimal compared with the resources available to any overseas government-backed partner. The resulting financial inequality would inevitably place the entire control of the Hotol project in overseas hands.

The announcement was greeted with shock and dismay by the British space industry. Mr. Roy Gibson, former Director General of the British National Space Centre (BNSC), accused the Government of "shortsightedness".

Lord Rippon said: "I was speechless with rage when I learned that the Government will not provide any more funds for one of the most advanced technology projects this country has ever developed".

Former Minister of State for Industry and Information Technology, Sir Geoffery Pattie, was appalled by the decision. He said: "There is no other country in the world that would treat a project of this sort in this way. It appears to be nothing more than a failure of will and a lack of vision".

During Prime Minister's Question Time in the House of Commons, Mrs Thatcher defended the Government's stance. She told MPs: "We think our research moneys could far better go to many other projects which would help our own people far more".

British Aerospace and Rolls Royce, the two partners in the Hotol project, completed a two year concept study last autumn at a cost of £3 million, half of which was provided by the Government through the BNSC. The study yielded such encouraging results that the two companies have been continuing research at their own expense.

BAe and Rolls Royce hoped to begin a Definition and Initial Development Phase this year at a cost reported to be in the region of £4-6 million, half of which the Government was expected to pay.

If this research proved successful a development and manufacturing phase would begin with the first Hotol making its maiden flight in about 1998.

Hotol's future now lies with international cooperation. It seems unlikely ESA will be willing to support the project as it is committed to the development of the Hermes shuttle craft. One possible European partner is West Germany, who could combine Hotol technology with the West German Sanger spaceplane to produce a hybrid vehicle. The United States and Japan may also be willing to collaborate. Both countries are developing their own space planes but Hotol research is said to be ahead.

The Hotol engine design is on the secret list and remains classified. This obstacle will have to be lifted if Hotol is to become an international project. So far, the Government has not indicated if it intends to declassify the RB 545 engine. Meanwhile a 'disappointed' British Aerospace is continuing research.

'Freedom' Space Station

On July 18 President Ronald Reagan announced that 'Freedom' will be the name of the International Space Station.

NASA administrator James C. Fletcher recommended the name Freedom to the President following a review of more than 700 suggestions sent to NASA by employees, contractors; international partners and the general public.

Budget Cut

The US Senate has rejected President Reagan's request for $967 million to begin the construction phase of space station Freedom, allocating just $200 million for the project.

The Senate approved the bill by a vote of 86-11, sending it to a conference committee with the House of Representatives, which has appropriated $902 million for the station.

The final decision on the space station funding has yet to be made, and NASA is deeply concerned. NASA Administrator James C. Fletcher said he was disappointed.

"If this is the ultimate outcome, it is a setback for NASA and a blow to this country's future in space," Fletcher said. "The Space Station is the key to our major goals of the future. It has been studied, analysed and weighted against alternatives, and the conclusion is that the time is now.

"To suggest a further delay will cost us technologically and economically. It also will raise questions about our reliability as an international partner. This especially applies to the Europeans, Japanese and Canadians who are cooperating with us in the Space Station project. I hope the conference committee will reverse this action and keep the Space Station on schedule," Fletcher said.

In addition to the conference committee work that must be completed before NASA's budget goes to the President, there also is a proposal to transfer $600 million from the Department of Defense budget to NASA's research and development account. The transfer would free some money for Space Station.

Ariane V24 Success

Just over a month after the successful flight of the first Ariane 4, the European launcher was back in action. At 23:12 (GMT) on July 21, an Ariane 3 was launched from pad ELA-1 at the Kourou Space Centre. 16 minutes later its payload was injected into Geostationary Transfer Orbit. Atop the launch vehicle were the Insat 1C and ESC-5 communictions satellite.

Ariane has launched 11 satellites in 11 months and successfully orbited 34 satellites since its first flight in December 1979. Arianespace has issued a new launch manifest, which covers flights through to the end of 1989 (see table below). It is of interest to note that Skynet 4B, the UK military communications satellite, has been scheduled for launch an flight 27 in November following its withdrawal from the shuttle programme in which it was due for launch in 1986.

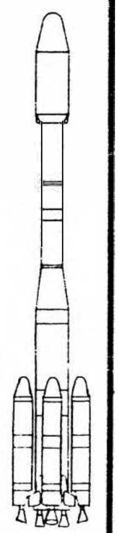
The Arianespace orderbook currently stands at 40 satellites worth approximately FF14 billion (about US$2.4 billion).

Parameters provisionally calculated on injection of the third stage were as follows:

Perigee:	198 km compared with a target of 189.1 km
Apogee:	36,000 km compared with a target of 35,988 km
Inclination:	7° for a target of 7°

Ariane Launch Manifest

Launch		Launch Vehicle	Satellites
Flight 25	SEP 88	AR 3	G-STAR III/GEOSTAR RO2 & SBS 5
Flight 26	OCT 88	AR 2	TDF 1
Flight 27	NOV 88	AR 4	ASTRA 1 & SKYNET 4B
Flight 28	DEC 88	AR 2	INTELSAT V F 15
Flight 29	JAN 89	AR 4	JC-SAT 1 & MOP 1
Flight 30	FEB 89	AR 2	TELE-X
Flight 31	MAR 89	AR 4	SUPERBIRD A & DFS 1
Flight 32	APR 89	AR 3	OLYMPUS
Flight 33	MAY 89	AR 4	TV-SAT 2 & HIPPARCOS
Flight 34	JUN 89	AR 4	SPOT 2
Flight 35	SEP 89	AR 4	INTELSAT VI F1
Flight 36	OCT 89	AR 4	SUPERBIRD B & INMARSAT 2F1
Flight 37	NOV 89	AR 4	TDF 2 & DFS 2



Insat 1C

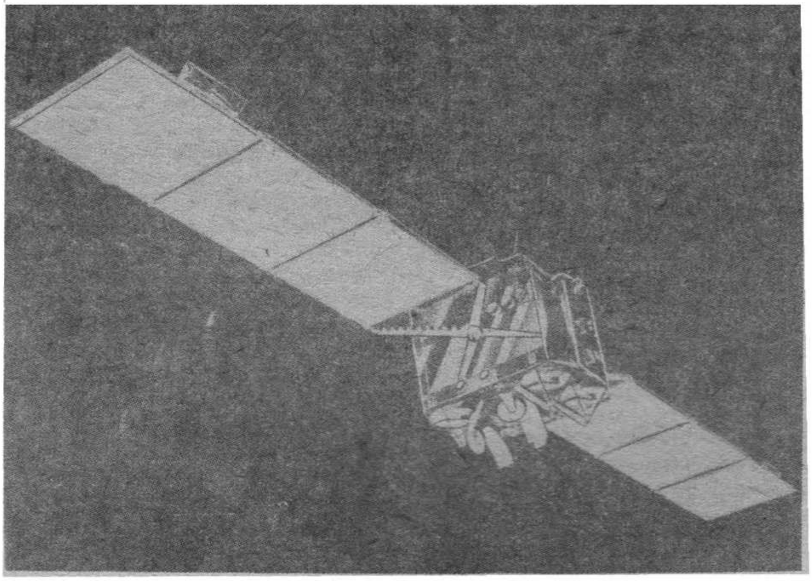
Insat 1C was launched for the Indian Space Research Organisation (ISRO) and it is one of three satellites that will provide communication links, TV broadcasting and weather data.

Among the satellite's many users will be emergency communications for major disasters utilising mobile ground terminals that can be transported by air or by road to the remote corners of India. During emergencies Insat 1C can relay voice and television transmissions.

While drifting to its geostationary orbit located at 93.8 degrees East, Insat 1C suffered electrical problems and how the failure will affect the satellite's operations is not yet clear.

Arianespace has been awarded the contract to launch the next generation of Indian communications satellites, Insat IIA and Insat IIB.

ESC-5 BAe



ESC-5

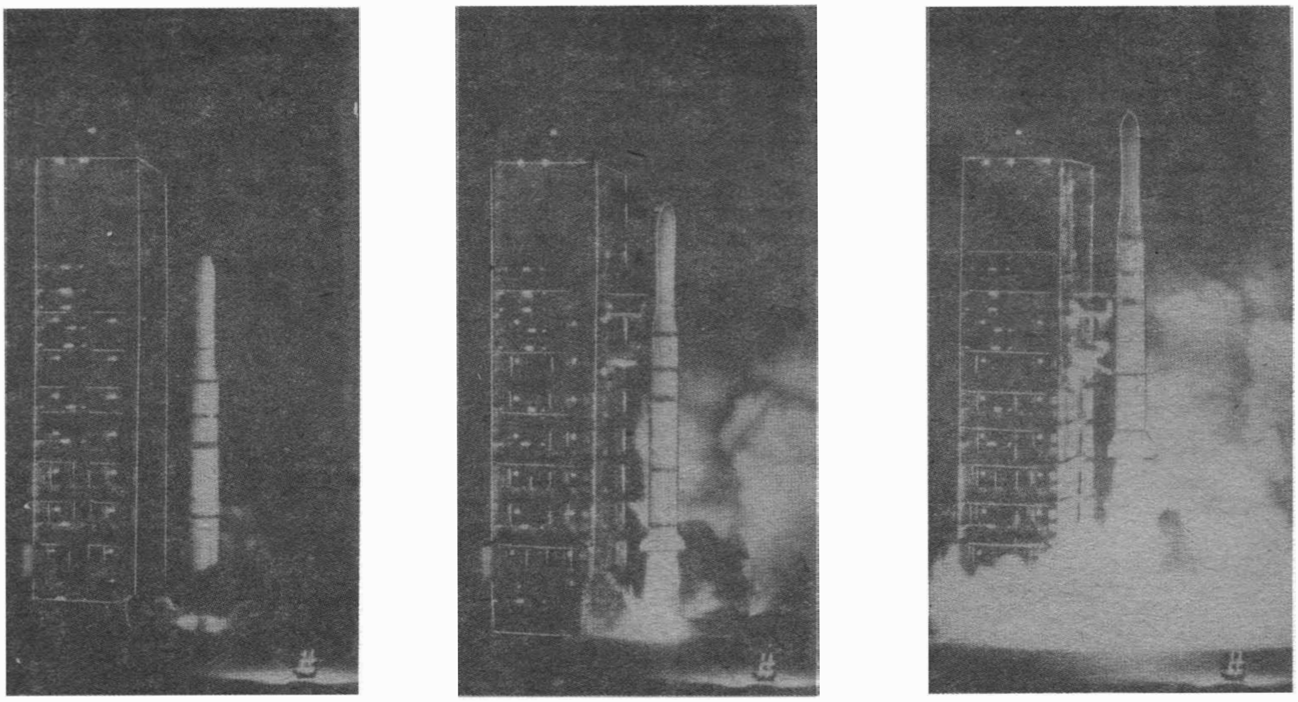
Beneath Insat 1C and enclosed within a Sylda payload canister was the ECS-5 European communications satellite which was designed and built for the European Space Agency (ESA) by an industrial team of about 36 major companies with British Aerospace as the prime contractor.

Once in orbit the satellite was despun and on July 23, its solar panels were deployed. The satellite's hydrazine thrusters were fired to cause ESC-5 to drift towards its operational location of 16 degrees East, arriving there on August 11.

The satellite is under the control of ESA's European Space Operations Centre (ESOC) at Darmstadt, West Germany. Once testing has been completed the satellite will be renamed Eutelsat I-F5 and control will be handed over to the Eutelsat organisation, which has a membership of 26 European countries. The satellite will then be controlled from the ESC Redu Control Centre in Belgium.

Eutelsat 1-F5 will relay telephone calls and television and radio programmes. It will join three Eutelsats currently in orbit.

INTERNATIONAL SPACE REPORT



Sequence of photographs showing Long March 3 launching a domestic communications satellite on March 7, 1988.

China Bids for Launch Business

China has refuted claims concerning its commercial launch policy and possible technology transfer involving satellites from the West.

A statement on Chinese space policy follows recent reports that pressure is being placed on the Coordinating Committee for Multilateral Export Control (CoCom) and the United States Department of State to restrict or prevent the usage of Chinese launch services for the launch of satellites developed in the US or Europe through technology transfer restrictions.

Mr. U. Keli, Vice-President of the China Great Wall Industry Corporation (CGWIC) said that China's entry into the world's launch service market does not constitute any competition with European or American launch service organisations.

"China is a developing country with limited manufacturing capability, capable of providing five to six launches per year with both Long March 2 and 3 vehicles, so that we can offer a total of 10 to 12 launch opportunities each year to foreign customers," he explained.

"It is clear that China's limited capability by no means constitutes competition or a "threat". In fact, China's launch service is a much needed supplement to the world launch service supply, and at the same time is a new option for the world's customers. This will accelerate the development of the world's space activity, particularly the satellite and telecommunications industry.

Mr. Keli said he would also like to reaffirm that the provision of launch services is quite distinct from the transfer of satellite technology.

"From the entry of the customer's satellite into China until its launch from China's launch centre, the satellite and related equipment will be under the exclusive control of the customer," stated Mr. Keli.

We will assist the customer in expediting the satellite's entry formalities, including exemption from customs examination. The customer can assign his personnel to guard the satellite at all times. China has no intention to derive any patent or technical know-who from the launch activities.

Mr. Keli gave an assurance that whatever steps necessary would be taken to safeguard the interests of foreign customers.

On the issue of costing, he reaffirmed that the prices of China's launch was composed of the cost plus "an appropriate amount" of profit.

"Because of the lower standard of living and labour costs in our country and because we do not seek exorbitant profits, the price of our launch services will inevitably be more favourable than that offered by some other suppliers.

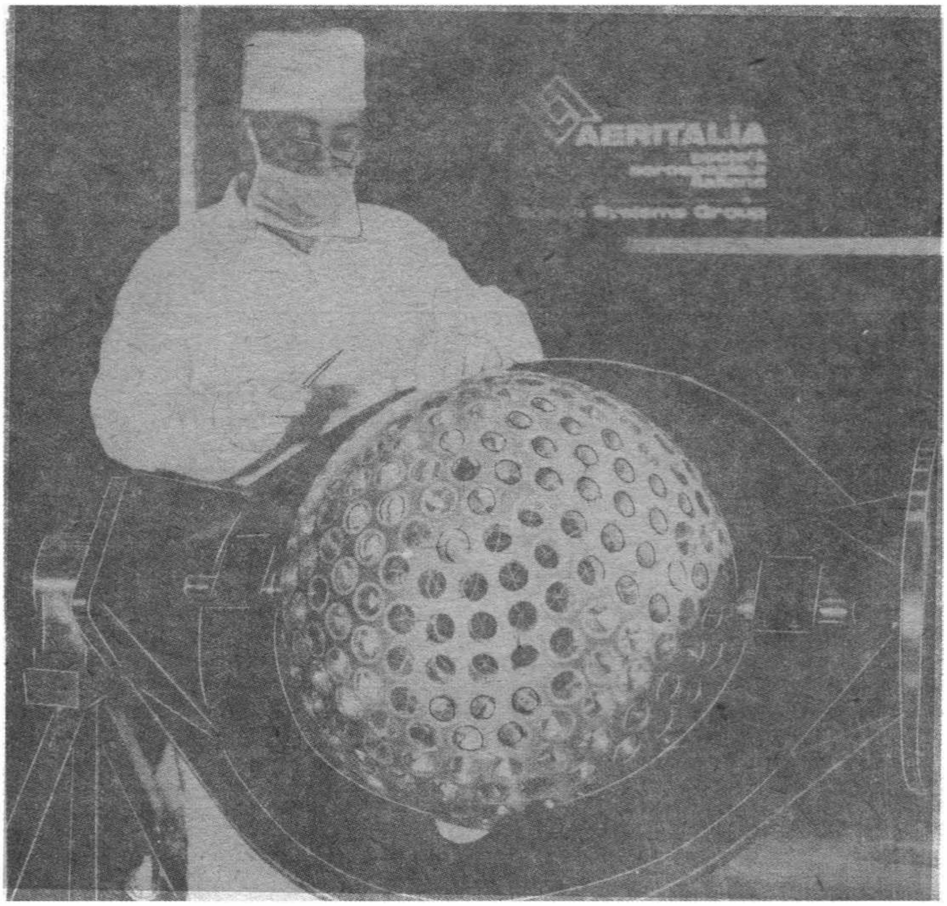
"Some Western figures have apparently claimed that our launch service "obtained high subsidy from government" and is being "dumped at low price". This is utterly unjustifiable. Under the recent economic reforms in China, China's enterprises must assume sole responsibility for their profits or losses. China Great Wall Industry Corporation is no exception. We do not obtain any subsidy from the government," he stated

"For a new kind of launch vehicle such as the Long March 2E, we are offering a promotional price when it is first used. Ariane's launch services, when developed and put into the world market, were also sold at extremely low prices. Ariane even provided a free launch for foreign customers. The new Ariane 4 launcher, which was just launched this month, was a demonstration/qualification flight" and the special pricing applied to the launch services for the three satellites launched. The same pricing policy was also implemented by US companies.

"China Great Wall Industry Corporation decided to follow this international practice for our newly-developed launch vehicles. We offer promotional pricing for the first two or three launch opportunities. Normal commercial pricing will apply to subsequent launches by these vehicles, as is already the case for Long March 3 launch services," added Mr. Keli.

INTERNATIONAL SPACE REPORT

Laser Reflectors on New Italian Satellite



The flight unit of the Lageos-2 satellite was delivered to the Italian National Research Council/National Space Plan (CNR/PSN) in July. The satellite was developed by the Aeritalia Space Systems Group under a cooperative agreement between the Italian and United States space agencies.

Like its predecessor, launched by NASA in 1976 and still in service, Lageos-2 (pictured left) is a passive, reflector-studded, spherical satellite that measures 60 cm in diameter. It is designed and built with such precision that its operational orbit will be extremely stable and, at anyt instant, its position can be determined with a high degree of accuracy. Consequently, the satellite will act like an orbiting reference point for geodetic studies such as measuring continental drift and relative fault movement.

A number of ground stations will fire a laser beam to the satellite whose 426 reflectors are designed in such a way as to return the beam to the originating station.

Measurement of the round-trip travel time and relative azimuth and elevation angles, and integrating the data from both Lageos-2 and Lageos-1, will make it possible to determine the relative movement between ground station positions with a sensitivity in the order of 2 cm per year.

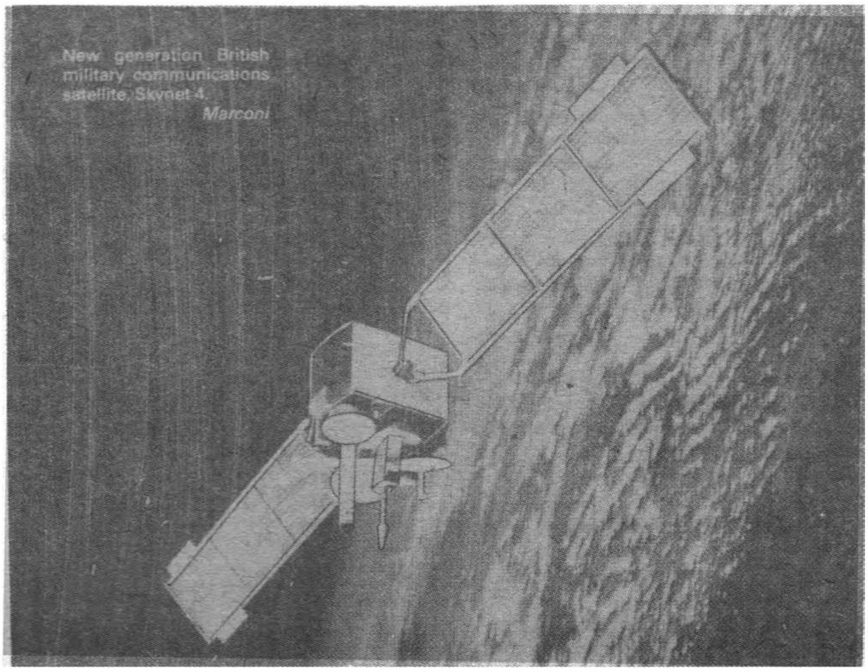
Military Comsat Research

Marconi Space Systems has been awarded a further extension to a Ministry of Defence Study contract, the deal is worth £1 million to the UK firm.

The research will eventually determine the scope and capabilities of the next generation of UK military satellite communications.

Marconi is currently the prime contractor for the provision of communications equipment for the Skynet 4 and NATO IV military satellite series.

Most recently Marconi has been awarded a major contract to provide equipment for the French Telecom 2/ Syracuse 2 communications satellite (***Spaceflight***, August 1988, p.311).



New generation British military communications satellite, Skynet 4. *Marconi*

Discovery Rolls Out

At 12.50 am local time on July 4 the Space Shuttle Discovery began its slow journey to Pad 39B at the Kennedy Space Center (KSC).

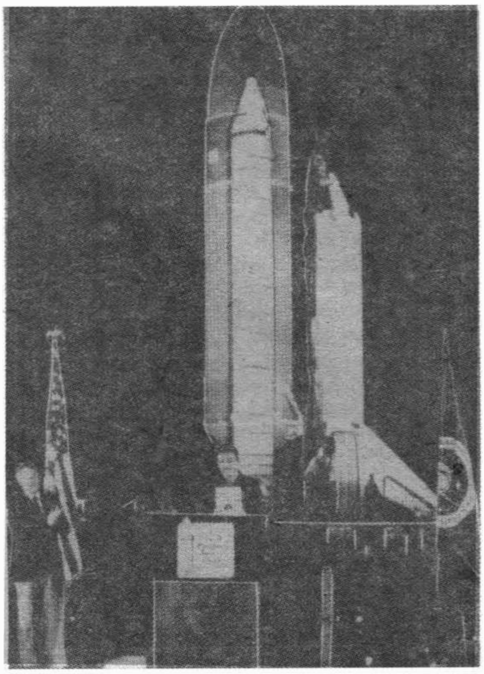
A shuttle roll out during the early hours of the morning is now standard practice. A major problem of transporting a shuttle to the launch pad is its vulnerability to the elements, a close watch is kept on the weather as heavy rain or debris blown in high winds could damage vital insulation. But the major problem is threat of a lightning strike to the vehicle. Analysis has indicated the best weather conditions at KSC are during the early hours of the morning, so during this time shuttles are moved to the pad.

The roll out became the centre point of the KSC's American Independence Day celebrations. As the shuttle cleared the massive Vehicle Assembly Building (VAB) it was greeted by the US national anthem accompanied by cheers from the several thousand spectators.

As Discovery continued its 4.2 km crawl to the pad, STS-26 Mission Specialist David Hilmers received a book containing the 15,240 signatures of all those involved with preparations for the flight. Hilmers told the crowd he would carry the book into orbit onboard Discovery.

The shuttle was "hard down" on Pad 39B at 8:42 am. Only the minimum amount of work was carried out once Discovery arrived to allow KSC employees to spend the rest of the July 4th holiday at home.

Shortly after midday the stack was enclosed within the Rotating Service Structure and connections made between the pad and the mobile launch platform. The next day Discovery's onboard systems were powered up and preparations began for the Flight Readiness Firing.



David Hilmers, STS-26 mission specialist, receives a book of signatures of those involved in preparations for the flight watched by Forrest McCartney, the KSC Center Director *NASA*

SPACEFLIGHT
NOTES FOR YOUR DIARY

1988

29 AUGUST
Joint Soviet-Afghan manned spaceflight begins.

SEPTEMBER
- STS-26, the first post-Challenger mission is due for launch.
- An Ariane 3 will launch G-Star III/SBS 5.

6 SEPTEMBER
Soviet-Afghan flight returns to Earth.

OCTOBER
- STS-27 (Atlantis) is to be launched on a DoD mission.
- The TDF-1 satellite will be launched by an Ariane 2.

NOVEMBER
- The second flight of an Ariane 4 will carry Astra 1 and the British military communications satellite Skynet 4B.

21 NOVEMBER
Soyuz TM-7 – the month long Soviet-French mission to Mir begins.

DECEMBER
- Intelsat F15 to be launched by Ariane 2.

1989

JANUARY
- STS-29, Discovery will deploy TDRS-D.
- An Ariane 4 will launch the JC-Sat 1 and Meteosat (MOP) 1 satellites.

23 JANUARY
The Phobos-1 probe will arrive in Mars orbit.

29 JANUARY
Phobos-2 will enter Mars orbit.

FEBRUARY
- COBE (Cosmic, Background Explorer) to be launched by Delta-184 from VAFB.
- TELE-X satellite to be launched by an Ariane 2.

MARCH
- STS-28 (Columbia) to be launched on a classified DoD mission.
- An Ariane 4 will place satellites Superbird A and DFS 1 into orbit.

APRIL
- STS-30 (Atlantis) to be launched carrying Magellan the Venus radar mapping probe.
- After three months investigating Mars the Phobos probes will turn their attention on the Moon, Phobos.
- The Olympus communications satellite is to be launched by an Ariane 3.

MAY
- NOAA-D to be launched from VAFB by an Atlas Centaur-68.
- An Ariane 4 will launch TV-SAT 2 and Hipparcos, a satellite for determining accurate positions of stars.

JUNE
- STS-31 (Discovery) to be launched carrying the Hubble Space Telescope.
- The Spot 2 Earth resources satellite is to be launched by an Ariane 4.

Note: All dates were correct at the time of going to press. Shuttle launch dates are for NASA planning purposes and subject to considerable change.

Indian Launch Failure

On July 13, the second flight of India's Augmented Satellite Launch Vehicle (ASLV) ended in failure.

The launch from the Shriharikota Space Centre seemed normal until all telemetry was lost 150 seconds into the flight. Minutes later the rocket plunged into the Bay of Bengal.

The Chairman of the Indian Space Research Organisation believes the fault lies in the first stage, which failed to build up pressure.

The first launch of the four stage solid rocket had a similar fate when its second stage malfunctioned (***Spaceflight***, May 1987, p.187).

Discovery Fuel Leak Problem

A leak of nitrogen tetroxide from Discovery's Reaction Control System (RCS) could require the shuttle to be rolled back to the Vehicle Assembly Building (VAB) for repairs with a possible launch delay of four weeks.

The leak is located in a half-inch dynatube fitting for the RCS oxidizer tank overflow vent. Technicians preparing for the Wet Countdown Demonstration Test first noticed the smell of nitrogen tetroxide around the left Orbital Maneuvering System (OMS) pod. Electronic sniffing devices were used to locate the leak in the region of the RCS oxidizer tank. The exact position of the leak was pinpointed with a 'cobra', a remote control device with a television camera and electronic 'sniffer'.

The leaking vent is used as a 'fill and spill' tube during servicing on the pad, it allows technicians to determine positively whether the tank is full. NASA officials believe the leak has been present since the dynatube fitting was disconnected and reconnected in October 1987. After the fitting was reconnected it was retested and showed no leakage. However when the system was pressurised in December technicians noticed a drop of 12 pounds per square inch in 16 days. The pressure drop was not pursued because it was so small and could have been caused by factors other than a leak, such as temperature changes or leaks in ground equipment.

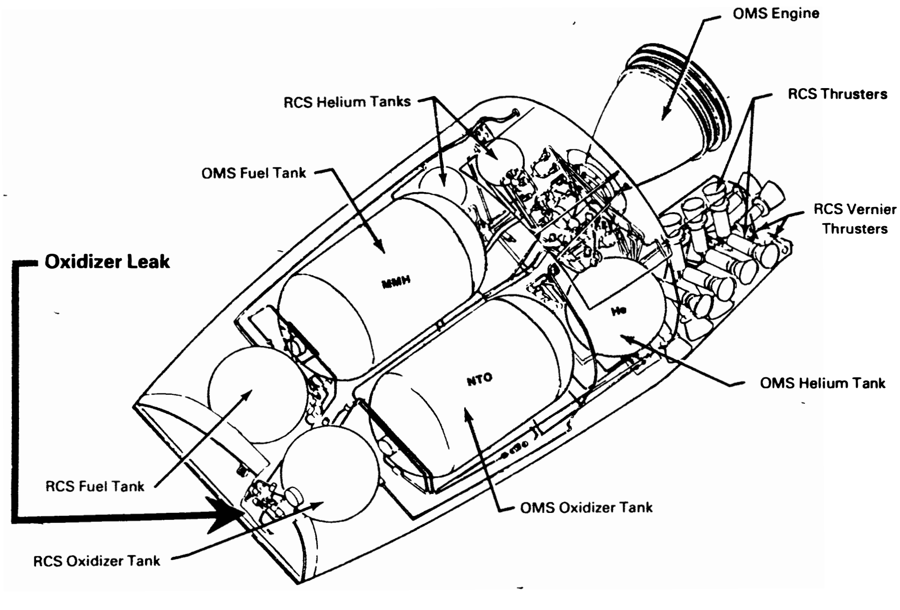


Diagram to show location of fuel leak.

Nitrogen tetroxide is an acid and if the leak was to grow the acid could chemically attack insulation and thermal blankets. Experts believe that the odds of the oxidizer interacting with any of those materials and starting a fire are low.

A number of repair options is being considered, as the leaking dynatube cannot be reached while the shuttle is on the pad, the nearest access port being about six feet away. The various options are:

- Discovery could fly without the 'minor' leak being plugged, but with new emphasis on safety it seems unlikely that NASA will take the risk. A similar leak went unrepaired during a previous mission.
- A plug could be inserted inside the vent line and worked into place between the leak and the main tank, preventing further escapes. This operation could be accomplished on the pad.
- Another on-the-pad repair would be to gain access to the dynatube by cutting through the shuttle's bulkhead. The leak would be enclosed within a 'clamshell' device filled with a sealant. However, before cutting through the bulkhead, engineers must be sure they can repair the incision.
- The shuttle could be rolled back to the VAB where the OMS pod could be removed and returned to the Hypergolic Maintenance Facility for repairs. Alternatively the OMS pod being prepared for Atlantis' STS-27 mission could be used. If Discovery is returned to the VAB the launch could be delayed until late October/early November.

A decision on which repair method to use will be made after the Flight Readiness Firing has been successfully conducted. NASA has said that there is a 50-50 chance of a successful repair on the pad.

Fuel Valve Delays Test

Launch preparations for STS-26 suffered a further setback on August 4, when Discovery's main engines aborted the Flight Readiness Firing. The problem could delay a second FRF by more than a week.

The 22 second firing was to prove that the Space Shuttle Main Engines (SSMEs) and their associated ground equipment were ready for an actual launch.

The countdown continued until T-5 seconds, just milli-seconds before the ignition sequence begins. One of Discovery's on-board SSME controllers detected a fuel bleed valve that was closing too slowly and the firing was aborted.

Later analysis indicated that the valve was closing correctly and the fault lay with an erroneous sensor.

Engineers from Rocketdyne, the manufacturer of the SSMEs, entered the orbiter's aft compartment the day following the aborted FRF. It was decided to replace both the valve and the faulty sensor. After reconnecting lines that had been removed to gain access to the fuel bleed valve, preparations for a second FRF attempt began.

● The FRF was successfully conducted on August 10.

Columbia Joins Atlantis at OPF

Columbia was towed to the Orbital Processing Facility (OPF) on July 8, after the high winds that had delayed the move died down. Columbia was brought from the Orbiter Maintenance and Refurbishment Facility to the OPF bay previously occupied by Discovery.

Atlantis is also in the OPF, where work to prepare it for STS-27 has been underway since March 1987. Work will now begin readying Columbia for STS-28, currently scheduled for March 1989.

Space Shuttle — The Return to Flight

Two and a half years after the Challenger accident NASA nears the end of its work to bring the Shuttle back into service. As Discovery awaits its launch from pad 39B of the Kennedy Space Center a new air of optimism can be found at NASA. Dr. L.J. Lawrence reflects on the causes of the Challenger explosion and on the recovery programme and its inevitable setbacks.

by L.J. Lawrence

Most people, when asked what caused the Challenger accident, might say O-rings, or a flawed Solid Rocket Booster (SRB). Those answers are correct in a superficial sense but as one might expect in an elaborate bureaucracy supporting a highly-complex, technological system, the root causes were much more insidious. In addition to faulty engineering, there were problems concerning organisational structure, communications flow, individual personalities, and bad luck.

Yes, bad luck to be sure. The faulty SRB joint vented a plume of flame which impinged upon the external fuel tank. It focused like a blowtorch on a bracket joining the tank and SRB. Had the flame vented just five degrees in either direction it would have been virtually harmless. It would have been detected in post-flight analysis and a joint redesign, already under evaluation, would have been stepped up as a result. The work might have been performed in parallel to Shuttle operations, which could have continued under more stringent launch constraints.

Bad luck also for the way in which NASA was perceived during that period. The Agency was obviously not as pristine as previously reputed, but neither was it in the disarray characterised by the media. It was unfortunate that the accident occurred at a time when there was a gap in leadership. James Beggs had just resigned as NASA Administrator. The Deputy Administrator had been in place a matter of weeks. The Director of Public Affairs had been with the agency two months. The director at NASA's Johnson Space Center, Houston, Texas, lead centre for Space Shuttle operations, had resigned weeks earlier and had not yet been replaced. This is not to suggest the leadership did not perform well following the accident. It is a simple fact of life that being new, they had not established the credibility and familiarity with each other and the NASA infrastructure – including the Congress and the media – which comes with time. As a consequence NASA's steady, underlying professional core was invisible and what came across to the outside world was confusion and uncertainty. A few months either way and the perception would have been quite different.

The breakdown of communications is a fascinating case study in itself. Post World War II society is replete with examples of the difficulty associated with communicating scientific and technical information. The Challenger accident highlighted these problems in circumstances ranging from interdisciplinary, organisational and technician-to-layman. One such conflict was the assertion among some engineers that the SRB joint would not function properly at certain temperatures, and the unwillingness among others to react to the new criteria. What was misunderstood is that during a launch countdown, managers want to know only if criteria are met, not argue whether they are correct. Criteria are established in advance in order to streamline the highly complex launch decision-making process. Simply stated, the SRBs were qualified to operate at temperatures between 40 and 90 degrees. Since the calculated lowest propellant temperature was 57 degrees, it was deemed safe to launch.

The process accommodates changes to criteria, but only through a precisely controlled and reasoned process that exists apart from launch preparations. Moreover, the tests which demonstrated O-ring performance to be unsafe below certain temperatures were suspect. Test articles were considered to be "low fidelity" – that is, not sufficiently representative of flight hardware to provide valid results. More miscommunication occurred within the organisation. The field joint concerns were largely unknown outside the SRB project office. The project manager at NASA's Marshall Space Flight Center, Huntsville, Alabama, signed launch constraint waivers for the SRBs on the Challenger mission as well as on the six consecutive prior missions. Neither the Associate Administrator for Space Flight at NASA Headquarters, Washington, DC nor the Shuttle programme manager, Johnson Space Center; nor the director of launch and landing operations, Kennedy Space Center, Florida, knew of the SRB launch constraint, or the reason for it, or of the waivers.

An expedient way to defuse public criticism following the Challenger accident would have been to assign blame and fire the responsible officials. If you are a humanist, you applaud NASA for rejecting this option and not wreaking professional ruin and personal trauma. Many senior officials resigned following the accident, but they did so without pressure or disgrace. Management rebuilding began with appointment of Dr. James Fletcher, a well-known quantity as NASA Administrator from 1971 to 1977, returning to the Agency's top post. It was also fortuitious that Rear Admiral Richard H. Truly was available for appointment as Associate Administrator for Space Flight. Admiral Truly piloted Columbia on the second Space Shuttle flight in November 1981 – the first time a space ship was reused. He then commanded the five-man crew of STS-8 in August 1983. Immediately prior to the appointment, he was first commander of the Navy's Space Command. His command experience, Shuttle background and all-round technical literacy made him uniquely qualified for the job. Moreover, his astronaut career imbued him with a particular credibility that is invaluable in relationships with the White House, Congress, media, and other elements of NASA's constituency. Also a key in the rebuilding process is Arnold H. Aldrich. A manager and engineer of extraordinary intellect, Aldrich was director of the Shuttle programme at the time of the Challenger accident and continues in the post. He is the only pre-Challenger manager still in authority. New direc-

Dr. John Lawrence is currently a member of former shuttle astronaut Richard Truly's staff in the Office of Space Flight at NASA Headquarters.

He joined NASA in 1980 as a Public Affairs Officer at the Johnson Space Center, Houston. His work included providing commentary from mission control during shuttle flights.

Previous to joining NASA Dr. Lawrence was the Director of Public Affairs for the Air Force's Space and Missile Test Organisation at Vandenberg AFB, California.

tors came on board at Johnson, Kennedy and Marshall space centers. Truly, who's space programme pedigree goes back to the mid-1960's, says programme management now is the strongest it has ever been.

Organisational changes occurred swiftly. An early action eliminated the "lead centre" concept, under which NASA field centres exercised principal control over specific programmes. Truly established a strong central authority at Headquarters. Aldrich, as Shuttle programme director, moved from Houston to Washington and into an office only a few steps from Truly's. A revitalised management council was composed of Truly, Aldrich and the centre directors. Monthly, free-wheeling, no-holds-barred council meetings are conducted at which programme issues and concerns are flushed into the open and relentlessly pursued to resolution. After observing the council at work, it is difficult to imagine an O-ring-like issue ever again escaping scrutiny.

The renewed concern for safety was formalised by creation of a new staff office under the NASA Administrator. At the time of the accident, the office of Safety, Reliability and Quality Assurance (SR&QA) was an element under the Shuttle programme manager. In recognition of the imperative need for sustaining these concerns, the word "Maintainability" was inserted into the title and SRM&QA was elevated to greater prominence in the organisation. Additionally, a new safety reporting programme was established. Based on a system in use in the Federal Aviation Agency, the programme promises the attention of senior managers to anyone having knowledge of an unsafe practice or situation. The programme guarantees anonymity to those who desire it. It is managed by a contractor from outside the NASA organisation to assure reponsiveness and serve as a buffer between the agency and the complainant.

SRB Redesign

Immediately following the accident NASA naively estimated the Space Shuttle would fly again in approximately one year. But the SRBs are perhaps the longest lead time item among all Shuttle systems. It is heavy industry, extremely labour-intensive, and requires a complex and time-consuming test cycle. Redesigning the field joint was a comparatively quick process. Test and verification was cumbersome.

The fitting in question is called a "field joint" because it is assembled at a field centre – Kennedy Space Center (KSC) – as opposed to the SRB factory near Salt Lake City, Utah. For ease in transportation and handling, SRBs are delivered in four major segments which are integrated at KSC. The redesigned field joint incorporates several improvements. Its tang-in-clevis design resists joint rotation – the deflection which occurs from internal pressurisation during firing. A third O-ring is present. A particularly innovative feature is the J-seal deflection gap. This groove in the insulation channels pressure in such a way as to "pinch" shut the bondline under great force. The insulation bondline is the path through which hot gasses must travel in order to escape the joint. The design has performed exactly as predicted in numerous tests, including several full-scale firings. Five such full-scale tests will have been conducted before the Discovery flight. The joint's performance has been so effective that deliberate flaws have had to be introduced into test hardware to verify the redundant characteristics of the design.

Another SRB redesign was performed on the case-to-nozzle joint. On several Space Shuttle flights there was significant distress seen in this area, to the extent that a redesign was deemed prudent. The work was performed in parallel with the field joint redesign and so had no adverse impact on the return-to-flight schedule. This redesign increases the number of radial bolts, adds an O-ring, and also incorporates a J-seal gap. It, too, has performed flawlessly in testing.

Not all the SRB redesigns went so smoothly. An outer boot ring (OBR) segment did not perform as designed and was ultimately responsible for a delay in the Discovery flight date. The OBR provides thermal protection for a nozzle flex bearing, which must be reused on subsequent flights. The OBR never failed to perform this function during flight or in tests. However, based on flight experience, engineers wished to add a further safety margin. Two alternative designs were developed. One would be evaluated on the Development Motor (DM) 8 test, August 30, 1987, and the second on DM 9, December 23, 1987. Computer analysis predicted the DM 9 version to be the more durable. To save time in the processing schedule the DM 9 design was selected for STS-26 and production of the flight hardware was authorised. But the computer predictions were wrong. The boot ring designs in both tests accomplished their purpose of protecting the flex bearing, but the DM 8 version provided a significantly higher safety margin. It was tested again during a full-scale firing April 20, 1988, and was found to have less wear than any OBR previously observed. The mid-stream decision to change flight designs made it impossible to meet the planned June 1988 launch and forced a schedule slip to August.

The programme stayed on schedule through late-spring 1988. Soon after the flight SRB segments arrived at KSC for stacking, it became apparent another slip in the launch schedule was imminent. It was the first field experience with the newly designed, more complicated field joints and assembly of the SRBs was taking longer than planned. By mid-May the left SRB had been stacked and progress on the right stack was well behind schedule. Consensus at the June 23 Management Council Meeting was that a delay in launch scheduling was probable. After consulting with Dr. Fletcher, the launch target date was adjusted to early September.

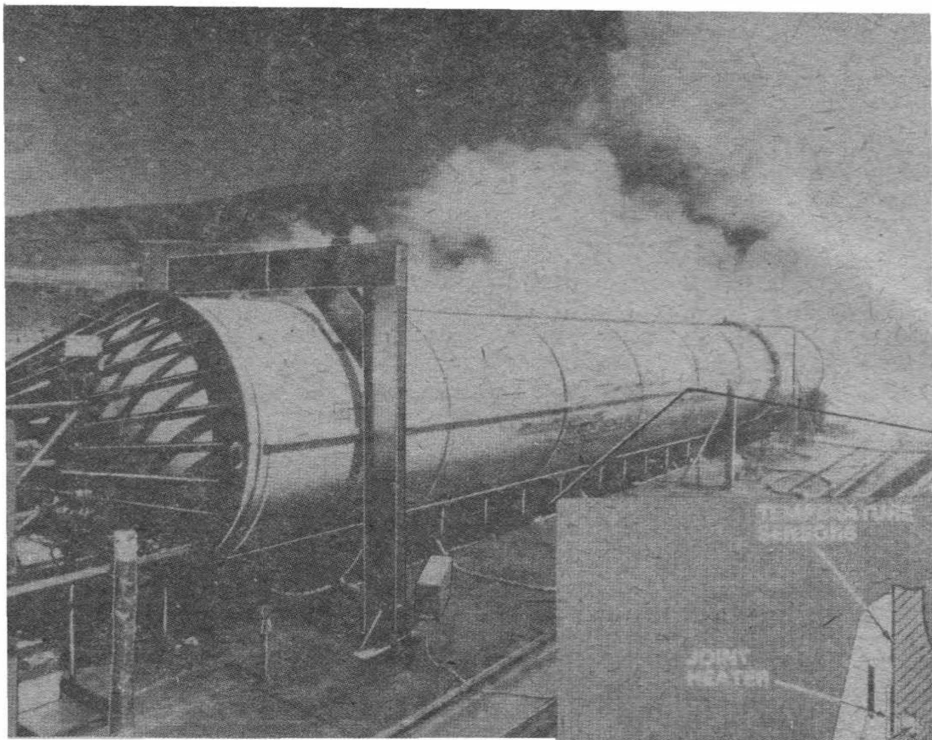
Other Changes

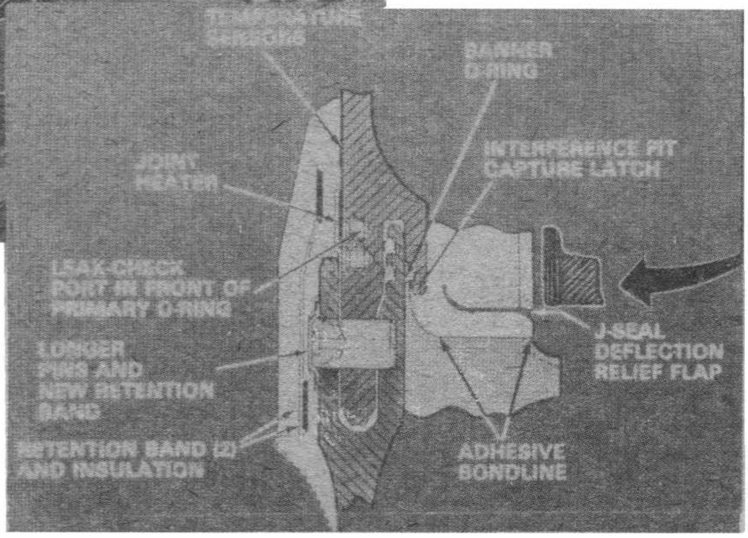
Meanwhile, in parallel to the SRB activity, Space Shuttle Main Engine (SSME) testing was conducted at an unprecedented rate. The main engine is the most advanced liquid propulsion system in the world. Three are located on the aft end of the orbiter and together produce 37 million horsepower. More engine test time had been accomplished since the Challenger accident than at any time prior. One engine in particular was tested for the equivalent of 80 Space Shuttle flights. They are designed to fly 10. Many improvements were made, but equally important is the tremendous volume of data generated which greatly enhanced the understanding of these extraordinary engines and their performance characteristics.

Another redesign was of the 17-inch quick-disconnect valves which stand between the SSMEs and the external tank. The SSMEs gulp liquid hydrogen and liquid oxygen at an astonishing rate – of the order of 20,000 gallons per second. Data showed that the valves oscillate during powered flight due to turbulence in this powerful propellant stream. This gave rise to concern that a leading edge of a valve might tip into the flow and be forced shut by the pressure, causing engine shutdown and catastrophic loss of the mission. The design fix was a pneumatic latch which rigidly holds the valve open.

Another Herculean task was the complete reassessment and recertification of the entire Space Shuttle system. A failure-mode-effects analysis, hazard analysis, and criticality review were performed on virtually every aspect of the programme, extending to both ground and flight operations. Each item of hardware was recertified in exhaustive detail. Particular concentration was devoted to criticality areas, which have direct influence on flight safety and mission success. An audit panel was appointed by the National Research Council (NRC) to verify the adequacy of the effect. It reported directly to the NASA Administrator. The NASA oversight committees in the US Senate and House of Representatives conducted additional hearings to monitor the effort.

The review resulted in more than 400 redesigns and improvements to Shuttle flight hardware. There were eight changes to the external tank, 30 to the SSMEs, 145 on the SRBs, and





A Solid Rocket Booster (SRB) is test fired at Morton Thiokol's Wasatch facility in Utah. The diagram is of the re-designed SRB field joint. The lines indicate the location of one of the three field joints on the SRB. *NASA*

220 on the orbiter. Hundreds of other improvements have been made to the launch support system at KSC, and the mission operations process at JSC. Every instance of design and testing was scrutinised by the NRC, which reported its findings to Congress and the Administrator. The result has been not only vastly improved hardware, but greater understanding of Shuttle systems and their performance margins. In every case, the effort has enhanced confidence in the overall Space Shuttle system and the organisation which operates it.

Future Flights Hit

In early spring, against this backdrop of recovery and optimism, the space programme was rocked by another colossal misfortune. On May 6, 1988, the Pacific Engineering and Production Company was destroyed by a fire and explosions which sent a shock wave across Henderson, Nevada, as though a bomb had fallen. Two died and hundreds were injured. Pacific Engineering manufactured about one-half the Free World's supply of ammonium perchlorate (AP).

AP is an oxidizer which, when blended with a powered aluminum fuel, constitutes the propellant used in SRBs. Each Space Shuttle flight set uses 1.7 million pounds of AP. Propellant for the first four shuttle flights had already been delivered. But beyond that the reduced production capability combined with the competing needs of other civil and Defence Department users puts the schedule of future Shuttle missions in question. NASA is working with the Defense Department and other interested agencies to develop a production and allocation strategy which equitably distributes the resource. The situation is sure to cause adjustments in the Shuttle manifest, and loss of one or two flights appears likely. But until several variables are known, such as on-line dates and production capacity of new facilities and the relative priorities of the various AP consumers, the specific impact remains uncertain.

The AP threat to the Shuttle schedule coincides with a subtle shift occurring in the focus of NASA's concern. With the launch of STS-26 now imminent, managers are beginning to worry about the downstream manifest and sustaining the heightened safety awareness. STS-27 flight hardware has begun arriving at KSC in preparation for an October 1988 launch. Nine flights are manifested in 1989 and nine more in 1990. Thirty astronauts are presently in training for the next six flights. Their concern is exacerbated by a shortage of funds and, consequently, manpower, being experienced at NASA's space centers. At Kennedy Space Center, where launch preparations are highly labour-intensive, the projected increased launch rate translates into a need for hundreds more workers. Whether Congress will provide a budget that answers this need is uncertain. The President submitted to Congress a NASA budget request for $11.5 billion for fiscal year 1989 – a 30 per cent increase over the previous year. The amount was characterised as the minimum necessary to rebuild the nation's space programme. However, the climate in Congress is one of austere funding.

In Conclusion

Fortunately NASA is an organisation which functions best when faced with a challenge. Today there is unwavering confidence that the Space Shuttle will return to flight and the programme will be stronger, safer and more successful than ever. But one need not scratch too deeply beneath this optimism to uncover the legacy of the Challenger accident. It is the renewed awareness that risk can never be eliminated from space flight. So long as humans are fallible, so will their machines be. Because the laws of physics are irrefutable, improving machinery is comparatively easy. The human factor is the more difficult side of the equation. NASA's restructured organisations, revitalised safety programmes, and renewed emphasis on communications will be effective for at least as long as its corporate memory includes that ugly stain in the sky over launch complex 39B. Beyond that, it will become part of the NASA tradition to hand down the legacy of Challenger – the supremely ironic lesson that high-tech accidents invariably result from low-tech causes.

The Long Road to Recovery

by Roelof L. Shuiling

The US Space Shuttle's return to flight has taken almost three years. The OV-103 orbiter Discovery last flew on STS-51I which was launched on August 27, 1985. Prior to the STS-51L launch in January 1986, Discovery's next flight had been planned for mid-July of that year on what would have been the first shuttle flight from Vandenberg Air Force Base, STS-62A. Discovery was to have been used for most of the Vandenberg polar orbital launches but problems with activating the west coast launch site and the loss of Challenger led to the decision to base Discovery permanently at the Kennedy Space Center (KSC). The US Air Force does not currently plan to reactivate Vandenberg as a shuttle launch site.

The space shuttle Orbiters have had a number of modifications to upgrade operational utility, improve safety and enhance performance during the period following STS-51L. Discovery went through a period of extensive unpowered modification and re-work which lasted from mid-February to August of 1987. On August 3, 1987 powered-on testing of the modifications began and lasted until early October.

The defined beginning of a shuttle mission's pre-launch processing is termed the "Up Mission Processing Start" (UMPS). For STS-26, UMPS occurred on October 2, 1987 with Discovery in Bay 1 of the Orbiter Processing Facility (OPF). Checks on the Orbiter's propulsion and communication systems lasted several months.

The 17 inch liquid hydrogen and oxygen disconnects were installed and tested. Modifications to allow a crew escape system installation began in late 1987 and continued, until the first part of 1988. There were two proposed methods, one involving a small rocket to pull the crew clear of the Orbiter, the second option letting the crew slide out and down a pole to clear the Orbiter wing. Both of these methods could only be used during gliding flight and the pole escape method (***Spaceflight***, May 1988, p.199 and June 1988, p.239) was eventually selected.

In January of this year, the Space Shuttle Main Engines (SSME) arrived for installation. Engine number 1 (serial 2019, with 14 starts and three flights) was installed on January 10, engine number 2 (serial 2022, with eight starts and no flights) and engine number 3 (serial 2028, with three starts and no flights) were installed on the 25th.

Interface verification tests on the three main engines were accomplished in February. Due to concerns that screws in the engine's high pressure turbopumps may have backed out, these pumps were removed, inspected, and reinstalled during March and April. All turbopumps successfully passed the subsequent inspections.

Discovery's Orbital Manoeuvring System (OMS) was installed with the right side OMS pod installation on January 29, followed by interface check out tests and the left side OMS pod installation on February 22 and 23 with interface check out tests immediately following.

These pods contain the manoeuvring engines which the Orbiter uses to change its orbit during flight, and the pods form the prominent humps on the top of the aft fuselage. Concerns regarding the right side OMS pod led to its later removal and repairs to both the primary and backup engine controllers were made in April. The pod was then reinstalled and the interface reverified.

The Forward Reaction Control System (FRCS) pod was installed and tested in March. The FRCS pod contains attitude control reaction jets and it fits into the upper orbiter nose area, just forward of the windshield.

During March, the Orbiter Autonomous Supporting Instrumentation System (OASIS) was installed. OASIS is designed to collect and record a variety of environmental data during several flight phases. The 230 pound unit was mounted in the aft port side of the payload bay, ready to be connected to sensors which measure strain, sound, temperature and pressure values. Tests of the OASIS later revealed a fault and removal and checks showed the problem to be in the recorder. After elimination of the fault, the retests in the orbiter were successful.

The crew waste management facility, or bathroom, and the galley were installed and tested in April along with the air filter system. Cabin pressure was checked and the landing gear tyres were installed. During this period checks of various subsystems such as hydraulics, propulsion, Ku band and radar antenna, thermal control and electrical tests continued. Late in April, astronauts arrived from Houston for a familiarisation exercise in Discovery's cabin.

Simulated emergencies involving flight crews were carried out in early May. One exercise involved an on-pad emergency occurring at the end of a launch count and another was a simulated landing emergency with a mockup of the orbiter crew cabin at the landing site.

Propulsion leak checks were continued and the main engine heat shield was installed. The forward payload bay television installations were made with the aft television installations to be done on the launch pad. The Master Timing Unit was installed and several days of checks performed on that unit, which acts as the Shuttle's internal clock.

Also in May, landing gear anti-skid controlling devices were installed and checked out. Flight control surface confidence checks were made with an astronaut operating the control surfaces from the orbiter's cockpit. The payload bay doors were closed and structural leak tests were made. Thermal barrier installation around the landing gear doors was completed and landing gear door cycle tests were done. Propulsion system leak checks were also completed.

Early in June, the landing gear ordinance was installed, the payload bay was cleaned and final payload bay closeout activity completed. The landing gear system and the payload bay doors were functionally checked and the payload bay doors were closed for the final time prior to payload installation.

Launch Simulation

On June 7, a simulation of the launch of Discovery was held at KSC. This exercise, termed the "Super Simulation", verified the changes which had been made to the management and operational aspects of the Shuttle launch. The simulated launch involved a nationwide network of facilities, control rooms and personnel.

Since Discovery was not actually on the launch pad during this activity, the flight crew performed their actions aboard the Shuttle simulator in Houston. They were linked to the launch and flight control stations by data lines and the simulation included several built-in problems during the countdown, as well as a simulated failure of the left main orbiter engine during ascent. The engine failure necessitated a simulated return to a landing at KSC.

In early June Discovery was powered down for the final time in the Orbiter Processing Facility (OPF) and taken off the jacks which had supported it. A final weight and centre of gravity determination was made and Discovery was towed from Bay 1 of the OPF to the transfer aisle of the Vehicle Assembly Building (VAB) in preparation for its


Astronaut Rick Hauck, STS 26 mission commander dons the new partial pressure suit re-introduced to Shuttle missions for emergency egress at high altitude as described in *Spaceflight*, June 1988, p.239. *NASA*

mating with the external tank which would contain the liquid fuel and oxidiser for the main engines. The external tank had previously been attached to the two Solid Rocket Boosters (SRBs).

Solid Rocket Boosters

Between January and March components of the shuttle's SRBs started arriving at the Cape and SRB stacking activity began, with the left SRB being mounted on Mobile Launch Platform (MLP) number 2 in the VAB's high bay 3. During this period, concerns over possible debonding between insulation and casings led to inspection and repair activity that caused some delays in the SRB stacking. The four segments of the left SRB (aft, aft centre, forward centre and forward) were stacked in March and April.

The right SRB stacking began in May and was accomplished during that month. Both left and right SRB forward assemblies were then installed. In June, SRB closeout operations on the field joints were completed with instrumentation sensor and moisture seal installation and the application of bonding material.

The two 149 foot tall SRBs on MLP number 2 were then joined to the external tank. External tank number 28 had arrived at KSC in April of 1985, and it had been undergoing its own test activities in high bay 4 of the VAB since February, 1988.

Space Transportation System

The Space Transportation System (STS) consists of the orbiter, the external tank and the two SRBs. STS-26's components came together in the 525 foot high VAB in June. The Orbiter Discovery was towed into the VAB from the OPF and it was then lifted into the upper reaches of the VAB, over the structure connecting VAB towers E and F, and then lowered into high bay 3 until it was just above the MLP number 2.

Discovery was then mated to its external tank. The actual supports for the Shuttle system are the SRB bases, and they support the weight of all of the flight components on the MLP. Following the mating of Discovery to the external tank-SRB combination, interface tests verified the many connections that had been made. The MLP and STS-26 were then ready for the roll-out from the VAB to KSC's Launch Pad 39B.

After arrival at the launch pad, the connections which carry the commands, signals, power and services between the pad and the vehicle were validated. Hypergolic propellants for the OAMS and reaction control engines were then loaded aboard the Discovery.

Prior to a Flight Readiness Firing of Discovery's main liquid fueled engines extensive preparations were undertaken. A countdown demonstration test was performed with the main engine propellants loaded, followed by a practice launch scrub and recycle exercise. At the conclusion of the recycle launch countdown the three Space Shuttle main engines were fired for a short period to demonstrate the validity of the entire system. During this operation all space shuttle systems and support, with the exception of the payload and the crew, operated as in an actual launch. The test firing data was analysed and the pad cleaned following the engine firing test.

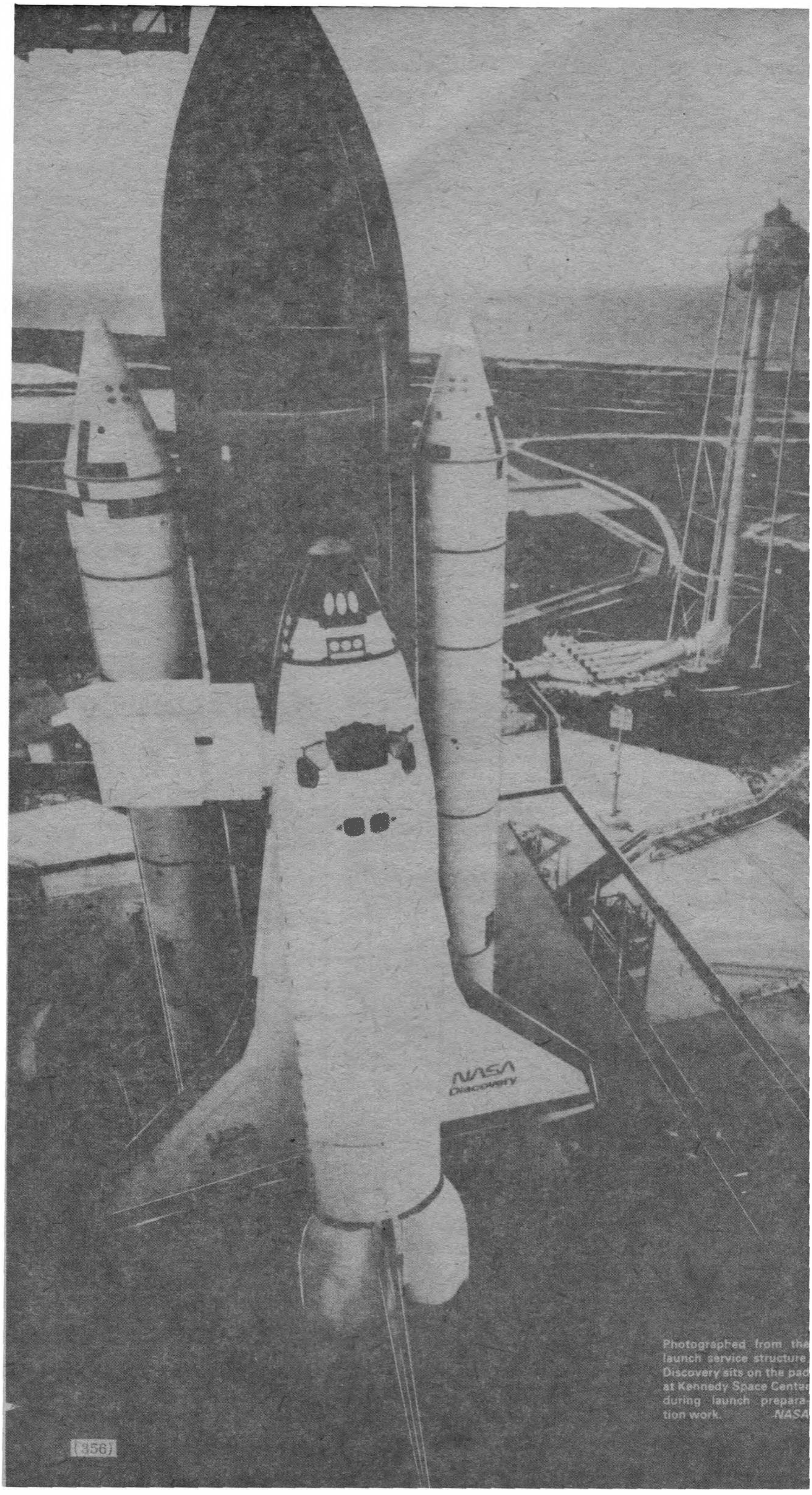
In normal Space Shuttle pad operation, the payload complement is brought to the pad first and is installed into the payload bay after the engine firing test with STS-26, the mission payload was not delivered to the launch pad until after that firing test.

The payload for STS-26 is the Tracking and Data Relay System Satellite (TDRSS) C and its solid fuel Inertial Upper Stage (IUS) transfer stage, which arrived at KSC in May and was mated to the IUS.

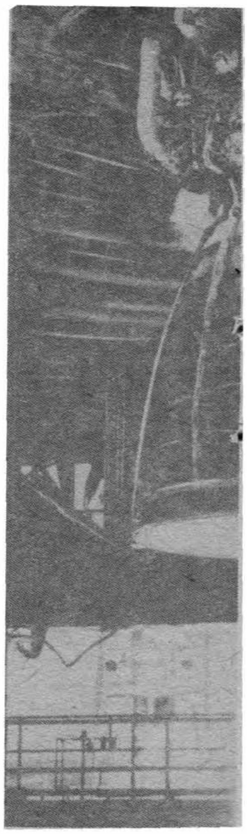
The combination of TDRSS C and its booster underwent integrated testing and when the payload arrived at the launch pad the satellite was loaded with hydrazine propellant and then installed in the Space Shuttle payload bay. Interface and data flow testing was performed to verify payload to orbiter connections and compatibilities with the TDRSS system.

Following the payload installation and tests, a final simulation was due to be performed.

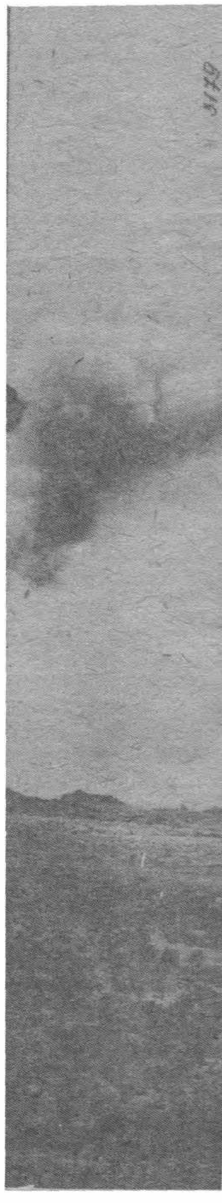
For the Orbiter Discovery, the path back to flight has been a long one. Only ten weeks had separated Discovery's previous two missions, STS 51G and STS 51I, in 1985. Now, over three years have passed since Discovery's last launch. The Discovery, and the nation's manned space programme, stood ready to return to the jobs for which they had been preparing.



Photographed from the launch service structure, Discovery sits on the pad at Kennedy Space Center during launch preparation work. -NASA



A shuttle main engine under



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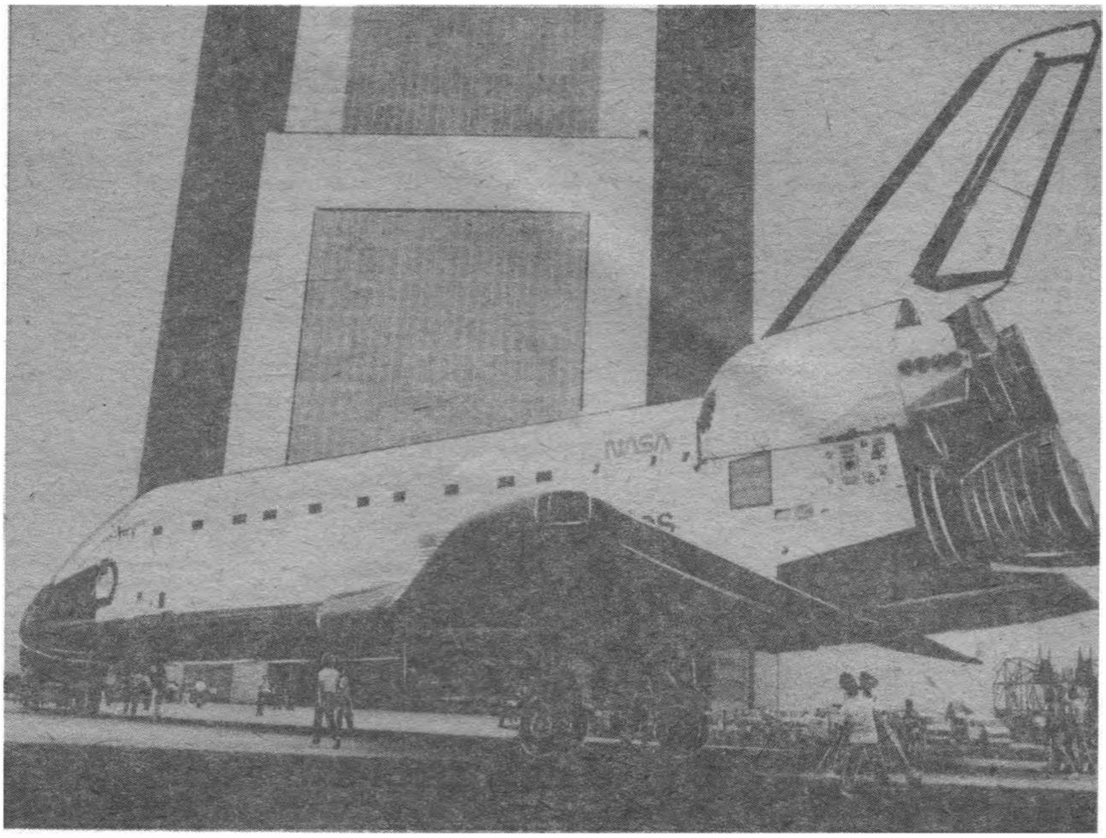
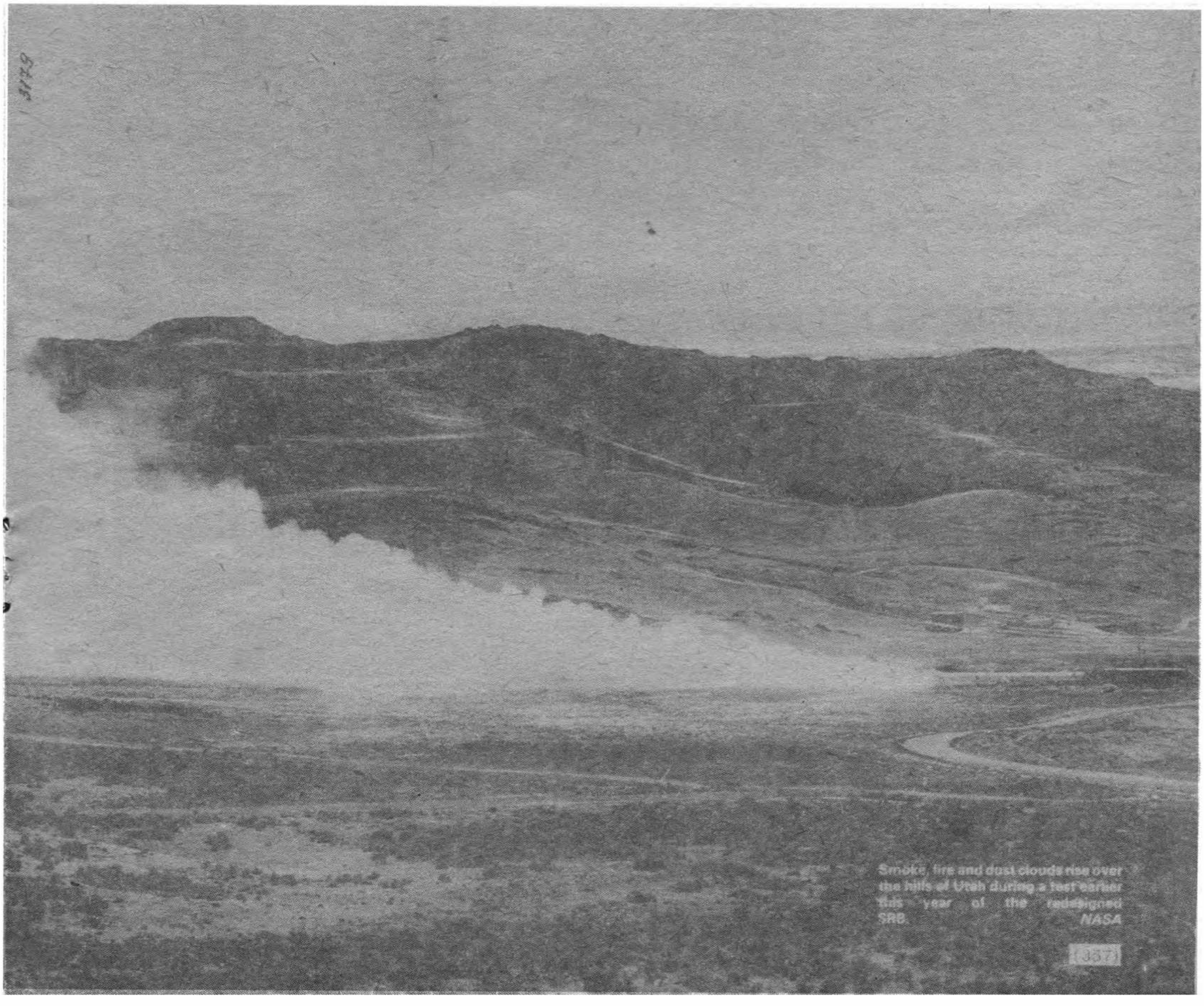


Discovery during transfer to the Vehicle Assembly Building on June 21. NASA



Smoke, fire and dust clouds rise over the hills of Utah during a test earlier this year of the redesigned SRB. NASA

Annual Report

Dynamic Year for Society

Officers of the Society	PRESIDENT C R Turner		VICE-PRESIDENTS Dr L R Shepherd G W Childs
Council Members	R A. Buckland Dr J.K Davies M.R Fry	Prof G.V Groves C R Hume A.T Lawton	Prof I.E Smith G V E. Thompson G.M Webb

Executive Secretary· L.J. Carter Deputy Executive Secretary Ms S A Jones

IAF President Dr Johannes Ortner (left) with Mr. John Butcher MP (centre), Parliamentary under-secretary of State for Industry, and Mr. Len Carter during the Joint Government/BIS evening reception at the 38th IAF Congress held at Brighton in October 1987.

The Society has maintained close international relations throughout its history and in 1987 it acted in its position as UK national member of the International Astronautical Federation (IAF) to host the 38th Congress of the IAF in October at Brighton.

The Society was pleased to welcome both individual participants and the many member organisations of the IAF together with the Federation's associated bodies, the IAA (International Academy of Astronautics) and the IISL (International Institute of Space Law) to this meeting which commemorated the 30th anniversary of the launch of Sputnik I by adopting as its theme: "30 Years of Progress in Space".

At the opening ceremory held at the elegant Dome Theatre of the Brighton Pavilion, addresses of welcome were presented by the Society's President, Mr. Rex Turner and by the President of the IAF, Dr. Johannes Ortner who emphasised the value of international cooperation in space projects. The opening address was given by Sir Raymond Lygo, Chief Executive of British Aerospace who also called for the challenge of space to be met by nations coming together and pooling their resources and sharing the problems and risks involved.

The main events of the week-long Congress were reported in 'Congress News' a special eight-page Society newspaper edited by Clive Simpson and distributed to delegates on the final day of the Congress and subsequently to Society members on request. A further report appeared in the December 1987 issue of ***Spaceflight***.

It was rewarding to the Society to see its detailed arrangements as host unfold to provide what most participants found to be a highly effective and enjoyable meeting. The Society sponsored two evening receptions for all participants in the Corn Exchange of the Brighton Dome Complex. The first was a Civic Reception held on Sunday, October 11, 1987 jointly with the Brighton Corporation. The second, held on the Monday evening, was the Government Reception attended by Mr. Butcher, MP, Parliamentary Under Secretary of State for Industry. During the Thursday night, the worst hurricane force winds in many years struck the S.E. of England causing considerable damage to property in the Brighton area. Only twice have hurricanes of such force been recorded in the area. The last was in 1703: the one before was the storm of 1588 which scattered the Spanish Armada. Fortunately, the Congress programme was able to continue the following day but the Banquet to be held on the Friday evening had to be cancelled due to power failure. In the following weeks many expressions of appreciation were received by the Society in recognition of its role as host to the Congress and of the helpfulness of its staff. Extracts from some of the letters received have appeared in the December 1987 and the January and February 1988 issues of ***Spaceflight***.

International Relations

The 30th Anniversary of the launching of Sputnik I in October 1957 was marked in London by the Science Museum with a reception held in the Museum's Space Gallery where many of the leading technical advances of the space era are on permanent display. The Society was represented at this event by L.J. Carter and Ms. S.A. Jones and the event was also attended by NASA and other personnel with senior space involvement, including former NASA astronaut Buzz Aldrin.

During 1987 the Society continued to follow developments in the United States space programme which was still facing the difficulty of returning to a normal launch schedule. Long-standing contacts with US companies and organisations were maintained, particularly with NASA establishments, and by visits by the Executive Secretary to Houston and Cape Canaveral.. The latest work at NASA's Jet Propulsion Laboratory (JPL) continued to be featured in 1987 issues of ***Spaceflight*** in the now well-known series of 'Space at JPL' articles authored by Dr. William McLaughlin. Technical papers from NASA establishments and related organisations were submitted to the Society for publication and appeared in two special issues of the Journal of the British Interplanetary Society (*JBIS*), one on Mission Automation Systems in October 1987 and the other on NASA Space Science in early 1988.

The Society continued to enjoy close relations with the European Space Agency (ESA) at a high technical level through the participation of ESA personnel at Society meetings and publication of their work. Papers submitted by staff of the European Space Operations Centre were published as a special issue of *JBIS* in June 1987. The Society is grateful for the continued receipt of ESA technical publications for its Library where they are available for reference by members of the Society during library opening times.

In 1987, the major events of world space activity were provided by the Soviet Union and the availability of more information on certain aspects of this work was a welcome trend as has been the generally improved climate of East-West relations. The Society has continued to follow with close interest the technical developments of the Soviet space programme and held an all-day meeting on this subject in 1987, the proceedings of which were subsequently published in a special issue of *JBIS* (March 1988) which quickly sold out due to heavy demand.

International Recognition and Presentations

Contributions by the Society to international cooperation and education were formally recognised in 1987 by presentations to it on two notable occasions.

In August 1987 at the Annual Congress of SEDS (Students for the Exploration and Development of Space) in Huntsville, Alabama, the 1987 Arthur C. Clarke award was presented jointly to the Society and its Executive Secretary. The award, which is presented annually to an organisation or individual in recognition of outstanding contributions to space education, already has a distinguised list of past recipients. The accouncement of the award stated:

"Since its founding over 50 years ago, the British Interplanetary Soc-

iety has led the world in prioneering space educational publications and activities. The Arthur C. Clarke Award for 1987 is especially dedicated to Mr. Carter's talents and efforts as Executive Secretary of the BIS. It recognises his immeasurable role in creating and guiding the Society's outstanding programmes in space education."

The Society's role in promoting international cooperation by hosting the 38th IAF Congress was recognised by NASA with a presentation in October at the Society's **SPACE '87** Exhibition at Brighton to the Society's President Mr. Rex Turner. The presentation was made by NASA astronaut Karol Bobko and took the form of an impressive framed picture featuring scenes from Col. Bobko's last flight in October 1985 and a Union Jack flag which had been in space. The picture carried the citation: "Presented to The British Interplanetary Society from the National Aeronautics and Space Administration" and a rider, "This British Flag and crew patch were flown aboard the Space Shuttle "Atlantis" STS 51-J, October 3-7, 1985".

BIS President Mr. Rex Turner (right) receives a presentation to the Society from shuttle commander Col. Karol Bobko on behalf of NASA at Brighton, October 1987.

Also at the Brighton meeting, Mr. Philip E. Cleator, who founded the British Interplanetary Society in 1933, was honoured by the American Institute of Aeronautics and Astronautics with the presentation of a Citation recognising his outstanding contributions to astronautics which led to the foundation of the BIS. The presentation was made by Larry Adams, President of the AIAA, during the History Session of the 38th IAF Congress at Brighton.

The Society was also the recipient of a momento of the early days of rocket development when, at the Brighton Congress, it was presented with a piece of the wreckage from a V-2 flown at White Sands in 1946 and not recovered until April 1986. The item beautifully mounted on polished teak, was given by Cpt. John London III, a Fellow of the Society, who presented a paper to the Congress on V-2 Operations at White Sands which emphasised the unique technical aspects of these early tests and their contribution to the success of subsequent American space developments.

On October 6, 1987 the Society was pleased to accept the presentation to it of the 1985 membership card of Charles Walker, astronaut and Fellow of the Society. The particular interest of this item is that it is the first BIS membership card to have been carried into orbit. It has now been framed for display together with its NASA Certificate of Authenticity. The membership card was carried by Charles Walker on his second mission into space on STS-51D which began on April 12, 1985 and was under the command of Col. Karol Bobko.

Members Honoured

In addition to the various forms of recognition of the Society in 1987, wide-ranging recognition has been given to members and others who work closely with the Society for their individual contributions to space and astronautics.

On May 20 1987, Arthur C. Clarke, Honorary Fellow of the Society and Chancellor, University of Moratuwa, Sri Lanka received the 10th Charles A. Lindbergh Award in Paris. In his acceptance address he outlined the role that 'Peacesats' could play in maintaining world peace, saying: "Establishing what I like to call "Peacesats" would present major political, administrative and financial challenges – but the reward might be nothing less than the salvation of mankind." Details of Arthur Clarke's Peacesat proposal appeared in the May 1987 issue of ***Spaceflight***.

In 1987 the Society reported in ***Spaceflight*** on the elections by the International Academy of Astronautics of many Society Fellows and others associated with the Society. Among those honoured were : R.J.H. Barnes, A. Bond, P. Culbertson, Dr. R.W. Holdaway, C.R. Hume, Dr. G.E. Hunt, Dr. W.I. McLaughlin, D.E. Mullinger, A.J. Smith, C.R. Turner and Prof. A.J. Meadows.

We were also pleased to report the award of the Academy's Engineering Sciences Book Award to two Fellows of the Society: Dr. David J. Shapland and Dr. Michael J. Rycroft for their book 'Spacelab: Research in Earth Orbit' published by Cambridge University Press.

BIS Fellow and astronomer, W.A. Bradfield of South Australia was honoured by having asteriod 3430 named after him during 1987.

Meetings and Activities

The main event on the Society's 1987 programme was **SPACE '87**, an International Exhibition of Space Technoloy, held at the joint venues of the Brighton Centre and the nearby Metropole Hotel on October 12-15. The 1,200 sq. metres of exhibition space, available for rent by industrial and commercial organisations and by national and international space agencies, was well taken up, providing a first-class display of current space technology and progress.

The exhibition was open to many categories of visitors including invitees of the exhibitors, members of University or Polytechnic Departments, participants at the 38th IAF Congress and members of the Society.

On the last day, designated 'Education Day', **SPACE '87** was attended by teachers and organised groups of school parties. More than 1000 school children and students attended **SPACE '87** on this day and special information packs were prepared in advance for all accompanying teachers. A lunchtime presentation of the Space Shuttle 51D mission of April 1985 by NASA astronaut Karol Bobko and McDonnell Douglas payload specialist Charles Walker was attended by 750 children in the Hewison Hall of the Brighton Centre and, for many, was a memorable highlight of the 'Education Day' programme.

Visitors to the British Aerospace stand at **SPACE 87** on 'Education Day' when special arrangements were made by the Society for organised groups of school parties and students to attend.

The significance of **SPACE '87** extended far beyond what earlier could have been foreseen, becoming a focal point of media attention in the wake of the UK Government's freeze on space expenditure and withdrawal from new ESA proposals for the 1990's. The Government's position was put by Mr. John Butcher, Under Secretary for Trade and Industry, speaking at a special luncheon after touring the **SPACE '87** Exhibition in which 30 UK companies took part. In organising and assisting with these arrangements the Society played a vital role in promoting debate on international space projects and, in particular, on the uncertainties surrounding the UK's future role, which by the time **SPACE '87** was being held had become a matter of major public and political concern.

The Society's influence over many years in promoting space is to be found in the extensive international and European cooperation and collaboration that is involved in present-day space programmes. In recent years, the Society has been aware of the need to persuade the Government to ensure a viable UK space activity for the 1990's and beyond, and one that would be adequately funded to enable this country to make a leading contribution in the international arena. In 1986, the Society was privileged to make representations of its space policy to the BNSC plan then being put together under the leadership of its Director-General, Mr Roy Gibson, and which was submitted to Government later that year but which has since never been published. In 1987, an invitation was recieved to submit views to the House of Lords Committee on 'United Kingdom Space Policy' sitting under the Chairmanship of Lord Shackleton. It was most gratifying to have the BIS statement published later as an integral part of the Report (in early 1988) and to see that the recommendations of the Report followed closely the BIS views in being critical of Government dithering on space policy and in advising urgent remedial action.

BIS space policy has been expressed from time to time in ***Spaceflight*** and by late 1987, was augmented by a ground-swell of support by members and ***Spaceflight*** readers expressing their views in the Correspondence columns of the magazine and also directly to the Government by writing to their MPs. Much technical and public interest continued to be attached to the Hotol spaceplane project in 1987 both on account of its novel design and as a potential area of space involvement for the UK in the 1990's and early 21st century. Through the work of its members, the Society has had a long-standing association with the development of the spaceplane concept and in November 1986, it proved possible, for the first time, to bring many aspects of the work into open discussion at a one-day symposium organised by the Society. In April 1987, a follow-on one-day symposium was held on 'Spaceplanes', with an international participation which brought into open discussion the current status of spaceplane concepts in countries such as France, Germany, Japan, the USA and Soviet Union.

A number of opportunities for members to participate in technical visits and evening lectures were provided in 1987. Two all-day technical visits were held on Saturday, October 17 each covering two major UK government establishments having space-related programmes. The day of these visits came at the end of the week-long IAF Congress so enabling overseas members who may have been attending the Congress to participate. The Society gratefully acknowledges the hospitality offered to it by the management and staff members of the National Remote Sensing Centre, Farnborough, the Meteorological Office, Bracknell, the Rutherford Appleton Laboratory, Didcot, the UKAEA Culham Laboratory and also the UOSAT Spacecraft Engineering Unit, University of Surrey for a further visit by many who attended **SPACE '87** and required further information.

Evening lectures, held in the Society's Conference Room, were well attended with audiences attracted by the expertise and popularity of the visiting speakers. We gratefully acknowledge the contributions of Dr. Garry Hunt, Frank Miles, Phillip Clark and Charles H. Martin, among many others, to this part of the Society's programme. The continuing assistance of Eric Waine with operation of the projection equipment at lectures and film shows, of which two were held in January and February, is also gratefully acknowledged.

Publications

Twelve issues of *JBIS* were published in 1987. These included special issues on Space Stations, Interstellar Studies, Pioneering Space and Space Science at the University of Birmingham as well as those mentioned above. We gratefully acknowledge the editorial and administrative assistance of the following whose unstinting efforts resulted in one of the Society's best *JBIS* annual volumes: Dr. G. Alfrey, Dr. E.J. Becklake, L.J. Carter, Dr. J.K. Davies, R.A. Flood, Prof. G.V. Groves, Dr. A.R. Martin, Dr. W.I. McLaughlin and C.A. Simpson.

The opportunities offered by *JBIS* for the publication of technical papers (with authors receiving 50 reprints without charge) were publicised in 1987 by announcements in *JBIS* and ***Spaceflight*** and a personal communication to all Fellows of the Society. The Society is grateful to all who responded and continues to urge authors and everyone in a position to guide the placing of technical papers for publication to send to the Society or to contact the Society for further details.

JBIS continued to be well supported by subscriptions from technical libraries in 1987 and also increasingly by personal subscriptions, being available at a much

reduced price to members of the Society. For the individual subscriber, *JBIS* offers a complementary interest to ***Spaceflight***, being at a specialist technical level compared with the latter, and therefore announcements have appeared in 1987 issues of ***Spaceflight*** listing the contents of the corresponding monthly issues of ***JBIS***.

Improved arrangements were introduced in 1987 for overseas members and subscribers to receive *JBIS* and ***Spaceflight*** by air-assisted delivery. Also, 12 monthly issues of ***Spaceflight*** were published compared with 10 in previous years, the two extra issues taking over from Space Education which was discontinued. One of the extra issues was a special issue in October commemorating the 30th anniversary of space exploration. Over 50 authored articles or features were published in ***Spaceflight*** in 1987 which, with news coverage and reports, embraced some 225 space topics. The extensive range of detailed space information provided by ***Spaceflight*** owes much to the dedicated work of Gerald Groves (Editor) and Clive Simpson (Assistant Editor), and our regular contributors such as Dr. William McLaughlin with 'Space at JPL', Neville Kidger with Soviet mission reports, Robert D. Christy with 'Satellite Digest', Theo Pirard with European News, and Len Carter, who prepared over 60 'Book Notices' in the course of the year.

1987 ACCOUNTS

Report of the Auditors

We have audited the financial statements in accordance with approved auditing standards and which, in our opinion, give a true and fair view of the state of affairs of the Society at 31st December 1987 and of its results for the year then ended, and comply with the Companies Act 1985

Ledger Mead & Sparks
Chartered Accountants

Income and Expenditure for Year Ended 31st December 1987

	Notes	1987	1986
		£	£
TURNOVER	2	181,308	160,638
COST OF SALES		(121,905)	(114,531)
GROSS PROFIT		59,403	46,107
Administrative Expenses	3	(68,412)	(65,470)
OPERATING LOSS	4	(9,009)	(19,363)
Bank Deposit Interest Receivable		9,977	12,424
SURPLUS FOR THE YEAR	5	968	(6,939)
Balance brought forward		102,584	109,523
BALANCE CARRIED FORWARD		£103,552	£102,584

Balance Sheet as at 31st December 1987

	Notes	1987 £	1987 £	1986 £	1986 £
TANGIBLE ASSETS	6	41,004		41,004	
INVESTMENTS	7	46,028		42,285	
			87,032		83,289
CURRENT ASSETS					
Debtors	8	6,200		5,905	
Cash at banks	9	52,081		39,092	
		58,281		44,997	
LIABILITIES DUE WITHIN ONE YEAR					
Creditors	10	41,761		25,702	
NET CURRENT ASSETS			16,520		19,295
			£103,552		£102,584
Represented by:					
ACCUMULATED FUNDS					
Balance at 1.1.87			£102,584		£109,523
Excess of Income over Expenditure for the year			968		(6,939)
Balance at 31.12.87			103,552		102,584

certified to be a true copy.

G.V. Groves and A.T. Lawton
Members of the Council

1. **ACCOUNTING POLICIES**
   (a) Depreciation has been provided at rates considered appropriate to reduce the cost of the assets to their residual value over their estimated useful life The rates used are·
   Freehold Buildings – 2% on a straight line basis
   Fixture, Fittings and Equipment – 10% on a straight line basis except for certain equipment at 25% on a reducing balance basis
   (b) Donations and income from specific fund raising events are set off against the cost of fixed assets

2. **TURNOVER**
   Turnover represents subscriptions receivable and income from the sale of publications.

3. **STAFF COSTS**

	1987	1986
Salaries and National Insurance Contributions	47,035	39,188

The average number of employees during the year was six full-time office and Administrative staff.

4. **OPERATING LOSS is after charging:**

	1987	1986
Auditors' Remuneration	500	975
Depreciation	–	2,856

5. **TAXATION**
   The Society has no liability to Corporation Tax.

6. **TANGIBLE ASSETS**

	Freehold Land and Buildings	Library and Equipment	Total
COST	£	£	£
Balance at 1.1.87	176,768	53,357	230,125
DEPRECIATION			
Depreciation at 1.1.87	22,764	201	22,965
Net Balance at 31.12.87	£154,004	£53,156	£207,160
Less: Contributions received to date	113,000	53,156	166,156
N.B.V at 31.12.87	£ 41,004	£ –	£ 41,004

7. **INVESTMENTS**

	1987	1986
Special Deposit Account	£46,028	£42,285

8. **DEBTORS**

Prepayments and Accrued Income	3,908	4,413
V.A.T. Recoverable	2,292	1,495
	£ 6,200	£ 5,905

9. **CASH AT BANK**
   In addition to the bank balance shown in the Balance Sheet £89,007 is held in separate deposit/Giro accounts in respect of 1988 subscriptions received in advance. (1987 : £72,038) and £7,289 in respect of donations towards an extension appeal.

10. **CREDITORS** – amounts falling due within one year

Tradecreditors	38,754	22,777
Other creditors and accurals	3,007	2,925
	£ 41,761	£ 25,702

Coat of Arms

As reported a year ago the Society was honoured in 1986 by a grant of arms and heraldic badge by the College of Arms. The design of the coat of arms, which has since been the subject of much favourable comment, was described in the March and September 1987 issues of ***Spaceflight***.

The Letters Patent, which is the document formally conferring the grant on the Society, was recieved by the Society in 1987 after many months of careful preparation by the College of Arms' heraldic artist. The document is reproduced on p.121 and is notable for its decorative border which appropriately depicts interplanetary space and incorporates a number of recognisable planetary features.

The grant of arms to the Society was reported in the December 1987 issue of The Heraldry Gazette, where the Society's heraldic badge was appraised as being 'particularly successful' and 'providing a most appropriate symbol of the Society's aims'. The badge appears regularly on the Contents page of issues of ***Spaceflight*** as the comet symbol in the top right-hand corner. The appropriateness of the design stems from the recognition that 'comets are natural travellers of interplanetary space, journeying from its outermost to its innermost regions and also possibly to interstellar regions'.

Also shown on the Letters Patent is the Society's standard, the design of which combines badge, crest and motto in accordance with heraldic practice, to good and lively effect. The document, which is entirely hand-painted, is a work-of-art in its own right and an item which the Society can be justificably proud to possess.

Committees

During 1987 the Council initiated a detailed review of the Society's Committee structure to decide how the Society's needs could be met most effectively. The review has been an on-going process based on a change of emphasis between committee and working group activity. The Council gratefully acknowledges the time and effort of those who have contributed to the Society's affairs during this time of change. In particular, the Library committee has continued its essential range of activities in support of the development and operation of our library with commendable devotion and within severe financial limitations.

Membership

The Membership of the Society at December 31, 1987, compared with December 31, 1986 was as follows:

	31.12.87	31.12.86
Fellows	2348	1566
Members	1256	1815
	3604	3381

Society's HQ

Fortunately, the October hurricane storm left the Society's premises relatively unscathed at the time, though subsequent torrential rains penetrated the roof causing considerable damage in the upper rooms. The urgent need to repair this damage and to enlarge the drainaways from the roof area provided the opportunity to put in hand long-standing plans for renovating that part of property which was originally known as No. 29 South Lambeth Road, as reported in ***Spaceflight*** (January 1988).

One of the follow-on projects to these renovations will be an extension at the rear of the premises for which planning permission has been granted. In the meantime the yard is being cleared and its access improved as part of the current work to prepare the way for the extension at a later date.

Finance

In May 1987, the Society launched a Building Fund Appeal with a target of £80,000 towards the costs of the proposed new extension referred to above (***Spaceflight***, May 1987). Many donations have already been received and the Society gratefully acknowledges the generosity and encouraging support that has been shown for its plans. The Fund has also benefitted from revenue from other sources such as the sale of Society items which was increasingly promoted during 1987. Reports have appeared in ***Spaceflight*** from time to time regarding the progress of the Fund which passed the £20,000 mark well within its first year of operation.

In 1987 the Society's income and expenditure both rose over the previous year, reflecting an increased programme of activities and level of services with higher related expenditures. The very close balance between income and expenditure (amounting to a 0.5 per cent surplus) is an improvement on last year's figure but does not provide scope for new initiatives and points to a continuing need to achieve a higher income.

Conclusion

The Society expresses its gratitude to all members of its staff for the enthusiastic way in which they have worked, often under difficult circumstances, to enable the Society to achieve an outstanding year of activities. In addition to our regular programme of meetings and publications, 1987 saw the Society ably shouldering the responsibility for hosting the IAF Congress in Brighton. The success with which these extensive arrangements were handled owes much to the help and practical support given by Society members and others who contributed so positively at the time of need. We extend our grateful thanks to all concerned.

1987 has been my third and final year in the office of President and I step down confident that the Society has a vital role to play in the future of space and astronautics and that it is well able to fulfil this role with the same imagination and reality that has characterised its past endeavours.

C.R. TURNER
President

BOOK NOTICES

Night Sky Photography

H.J.P. Arnold, George Philip, 27a Floral Street, London, WC2E 9DP. 1988, 152 pp, £9.95.

This book is intended as a basic guide for photographers who wish to widen their range to include astrophotography, as well to amateur astronomers wanting to add photographic records to their visual observations. It takes readers to the threshold of advanced astrophotography, having first provided a thorough foundation upon which to build.

It refers throughout, of course, essentially to photographic equipment, as distinct from astronomical instruments such as telescopes and equatorial drives. After evaluating modern black and white and colour films, the author gives advice based very much on his own experience.

Diagrams and photographs, practically all taken by the author, help to explain and provide a demonstration of the techniques described.

Stars and Galaxies – *Slide Sets*

Two further sets of slides are available from the Armagh Planetarium, College Hill, Armagh, BT61 9DB, Northern Ireland, UK., each for £11, (including pp). Overseas orders should add 10 per cent for air mail delivery.

The first set is entitled "Stars and Galaxies II". It contains twenty four 35 mm slides in false colour of some of the most spectacular objects in the sky. The second set is a further group of 24 slides entitled "Stellar Camera" which depicts mainly galaxy photographs taken with the UK Schmidt Telescope in Australia.

The first set complements the original "Stars and Galaxies" set of 30 slides which are still available from the Planetarium.

Proceedings of the 18th Lunar and Planetary Science Conference

G. Ryder, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England. 1988, 753pp, Hard Cover £60.00.

The rapid and broad growth in planetary studies over the past thirty years have caused us to look once more at the Earth as a planet, but this time from a different perspective, i.e. to compare it with other bodies in the solar system. Most of the other planets have now been photographed extensively and measurements of their environments made *in situ,* thus enabling such comparisons to be made, while meteorite falls such as Allênde and the wealth of recent finds in Antarctica have added extensively to the known samples of extraterrestrial finds and so enabled comparisons to be drawn from even farther afield.

The present volume, containing the papers presented at a Conference held in 1987, contains about sixty contributions under the general headings of the composition of lunar samples and areas surrounding the Apollo landing sites, the geology of the Moon generally, including cratering records and effects, and studies of the origin and composition of meteorites. A final section on other bodies in the solar system contains one paper on Venus, five on Mars and a final contribution on the structure of icy satellites.

Astronomy

A.E. Roy & D. Clarke, Adam Hilger, Techno House, Redcliffe Way, Bristol, BS1 6NX, England. 1988, 357pp, £15 (soft back), £45 (hard back).

The appearance of a third edition testifies to the value of this most creditable work which grew out of university and extra-mural courses in astronomy given by both authors over many years.

The book, in conjunction with a companion volume "Astronomy: A Structure of the Universe", was written to fill the need for a first-year university course in astronomy though it contains much of considerable interest to the serious amateur astronomer also.

It provides some of the basic mathematical tools and discusses some of the simple physical processes involved in the work which astronomers undertake which is concerned with the astronomical bodies themselves.

Economics and Technology in US Space Policy

Ed: M. Macaulay, Resources for the Future, 1616 P Street N.W., Washington DC 20036, USA. 1987, 270pp.

Underlying the discussions in this volume, the edited Proceedings of a Symposium held in June 1986, is the premise that a better understanding of the relationship between technology and economics is necessary if we are to profit from further technical and scientific space achievements. Several new ideas, representing significant departures from the status quo, are introduced to support this point along with suggestions for improving the management of space resources, particularly those relating to space transportation, future space station activities and satellite communications. There are other issues that loom large in the international arena, e.g. political and economic benefits of collaboration versus competition in Earth observations and space transportation.

Major points made by the authors include the unresolved problems of resource allocation which now impedes virtually every space activity. The vast potential of space transportation, for example, can be fully realised only if questions concerning US Government launch policy are answered - particularly those about stable, long-term pricing policies. A "seat of the pants" approach to the space station should be replaced with one more systematic and objective, though not everyone will agree with the further suggestion that, during the initial years of space station operation, a real-time computer program should be provided to allow potential station users to bid against each other for resources and priorities.

Although most of the scenario described is, necessarily, concerned with the US Space Programme, there are many lessons for the UK to learn as well.

Keyguide to Information Sources in Remote Sensing

E. Hyatt, Mansell Publishing Ltd., Artillery House, Artillery Row, London, SW1P 1RT, 274pp, £33.00.

Remote sensing - the observation of Earth from space - is becoming increasingly important both as an academic discipline and in an ever-increasing variety of applications.

This volume pinpoints world-wide sources of information on remote sensing. Part I outlines the history and scope of the subject, identifies and evaluates the principal organisations involved, the major print and non-print information sources and provides information on conferences and other events. Part II is an annotated bibliography; Part III is an international directory of organisations active in remote sensing, annotated to indicate the nature of their interests.

As with all such compilations, omissions occur in matters of detail. For example, references to the Society describe its film lending service but omit videos: sources of remote sensing material include ***Spaceflight*** but not the special issues of the *Journal of the British Interplanetary Society.*

Space Industry International

Ed: G.K.C. Pardoe, Longman Group UK Ltd., Westgate House, The High, Harlow, Essex, CM20 1NE 1988, 370 pp, £85.

This is an international space directory listing 750 organisations involved in the industry. It provides a picture both of the international environment in which the space industry operates together with statistics, market trends and profiles of public and international companies and organisations as well as many private groups, active within 12 chosen geographical areas.

A product index guides the reader to specific manufaturers and distributors. Personnel information is given on key staff and, where a country has no indigenous space industry, appropriate applications undertaken such as remote sensing and space communications ground facilities are detailed.

Race to Mars: The ITN Mars Flight Atlas

F. Miles & N. Booth, Macmillan London Ltd., 4 Little Essex Street, London WC2R 3LF. 1988, 192pp, £12.95.

This book, with the use of extensive colour illustrations, which include a substantial number of artists impressions, begins with a brief history of past unmanned Mars missions and then proceeds to discuss the preparations and other requirements for a manned mission. A full description of many of the surface features and the environment likely to be encountered are included in a gazeteer which extends to including descriptions of the two moons orbiting Mars, Deimos and Phobos.

Guardians

C. Peebles, Ian Allan Ltd., Coombelands House, Coombelands Lane, Addlestone, Weybridge, Surrey KT15 1HY, England. 1988, 418pp, £14.95.

This book provides a comprehensive guide to the world's military space systems: their history, development, technology and the interpretation and use of the data obtained.

US satellites under this heading include the early, erratic Discoverer, the successful Big Bird, ELINT satellites, Manned Orbiting Laboratory, ocean systems, early warning satellites and Vela, the high-orbiting nuclear detection devices. The author also discusses the Soviet equivalents of these systems and compares the two programmes to highlight differing technologies and design philosophies. He also describes the independent Chinese satellite programme, the developing French system and the UN-proposed "PeaceSat". Appendices include fully detailed lists of satellites under various categories.

This is a most interesting and readable book on an aspect of the development of satellite technology and applications which are rarely covered and thus provides a useful contribution to the literature.

Astronomical Centers of the World

K. Krisciunas, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU. 1988, 320 pp, £17.50.

Although developments in astronomy have been fostered by many observations throughout the ages there has usually been, at any one time, an outstanding centre which contributed particularly important observations or was the source of some outstanding theoretical advance.

This book provides an introduction to such observatories and to the astronomers that made them famous. By concentrating on the relatively small number of centres with outstanding claims to fame, the author lays out the foundations for some 2000 years of progress culminating at the present day. The book is neither a general history of astronomy nor does it provide any detailed discussion of the breakthroughs led by such scientists as Copernicus, Galileo, Newton etc. Nor, indeed, is it even a directory of astronomical centres of learning. The thrust of the text is that, at any given time, there was an astronomical centre with such equipment and staff that crucial work could be produced there, and nowhere else.

Although he begins with Alexandria and ends with the Hubble Space Telescope there is a notable omission in the lack of any referenece to any of the early Chinese observatories of records which spanned some two and a half thousand years.

Uranus & Neptune: The Distant Giants

E. Burgess, Columbia University Press, 562 West 113th Street, New York, NY 10025, USA. 1988, 188pp, $29.95.

Perhaps the most unusual and mysterious planets in our Solar System are those found on its outermost fringes. There we find Uranus, a large greenish-blue ball spinning nearly on its side, with deep icy oceans of water, methane and ammonia, a unique system of rings and satellites which feature a bewildering array of grooves and craters on their surfaces.

Neptune, much further out, is almost a twin of Uranus in size but vastly different in other ways and appears to be even darker and more forbidding.

This book summarises our current knowledge of both worlds, with much of the information on Uranus based on the fascinating data gathered by the recent flight of the Voyager 2 spacecraft. In fact, the epic journey of Voyager and an account of the difficulties to be overcome two thousand million miles from Earth is, in itself, a dramatic part of the book.

Voyager is now on its way to Neptune but is not due to reach the planet until next year. The author discusses the discovery of the planet, its presently known characteristics and provides a background to the Voyager 2 approach.

Finally, he turns his attention to Pluto, the outermost known planet and considers the possibility that there might be even more distant but undetected worlds.

CORRESPONDENCE

Hotol Funding

The Government's decision not to provide further money for Britain's Hotol project has been reflected in readers' letters indicating widespread dismay and disapproval:

Sir, I feel obliged to express my concern about the Government's great lack of foresight in withdrawing financial support for the Hotol project and the space industry in general. Space is one of the new advances in science and technology, which could help to provide a firm foundation for the industry and economy of this country.

Surely it is the duty of the Government to promote new avenues of industry for this country's future prosperity. If research is left to profit-motivated industrial companies, it will be slow and will fall far behind that of foreign competitors (who are fully supported by their governments). This will bring into doubt the competitiveness and continual existence of the British space industry.

DAVID GARBUTT
Lincoln, UK

Sir, The announcement that the Government will not provide any more funds for the Hotol feasibility study will cause dismay. The amounts required to continue the study into the next phase are not vast, being some £4-6 million. I sincerely hope that industry will at least provide this much to enable the work to continue.

It is claimed that full development of Hotol would cost £6 billion. The Government spends in *one year* over £4 billion to maintain mortgage tax relief, which merely inflates property prices. I hope the Minister responsible remembers such things next time "return on investment" is mentioned in the same sentence as "Space funding".

MARK S. DOBED
Herts, England

Sir, The recent cancellation of funds for Hotol leaves us all stunned. What is there left to represent a British future in space?

It seems to me that space research will have to be done by private individuals out of their own pockets. During the last few years I have been building up my own satellite receiving station with which I receive and analyse signals from a variety of spacecraft. I am now able to monitor a large number of satellites only one of which is British and that is UK6. Other satellites include the ESA Meteosat, American GOES and NOAAs, the Russian Mets and their Cosmos series.

It so happens that I was the person who switched off UK6 many years ago when following a career as a satellite controller in which I was fortunate to work with the UK series of satellites and then with the IRAS satellite (a joint international venture). I changed location and profession only to find my interest in satellites had not waned.

In my local astronomical society there are many young members, some of whom wish to work professionally in space research as I did, and I feel a certain helplessness in trying to advise them which fields are likely to be untouched by the Government. One of our members, Jason Semmens, has just won a competition, the first prize being a trip to JPL to see the Voyager encounter with Neptune. Such enthusiasm for space research is being stifled by Government shortsightedness.

The country will pay for these disastrous decisions in the future.

LAWRENCE HARRIS
Plymouth, England

Space and the Third World

Sir, Your February and May correspondence debated the paradox that the British Government, which rejects Hotol as a purely national undertaking, gives foreign aid to India, whose ISRO hopes to plan a space shuttle, even if only in the twenty-first century.

That Hotol is only feasible through an international consortium surely suggests the following constructive solution:

The British Government and British Aerospace/Rolls Royce should invite India's ISRO and Japan's Mitsnubishi to become partners in Hotol. British foreign aid to India could than be converted into seed money for this project.

Secondly, political science can refute Dr. Fiona Vincent's concern that abandoning space exploration will reduce poverty, hunger and disease. All third world countries who have developed into relative prosperity – Taiwan, Singapore, South Korea, Hong Kong, not to mention Japan – did so by massive investment in polytechs, state-of-the-art manufacturing, and solid research.

Carefully planned investment in electronics, satellite communications, weather forecasting and prospecting, will create jobs and the industrial infrastructure essential to similarly develop other empoverished third world states.

KEITH GOTTSCHALK
University of the Western Cape
South Africa

Promoting Space Flight Worldwide

Sir, I read in ***Spaceflight*** of the UK Government's apathy toward space and the letter writing campaign that you mounted.

Please be advised that there are those of us in the US who are also writing to our Congressmen and Senators about the deplorable lack of attention that space is getting on this side of the Atlantic, too.

Please continue to push for the advancement of space flight throughout the world as you have done in the past.

RANDY BOND
W. Jordan, Utah, USA

Space Technology Shortfall

Sir, In the United States as in the United Kingdom, political obligations have sometimes fallen short of reality as recent struggles with space technology in both nations testify. A failure in American politics to lead the exploration of space has created disastrous indecision over the American space station and, in Great Britian, a similar effect can be seen in the outright defeat of the British National Space Centre's forward-looking space plan.

Jobs, research and training have all suddenly been left hanging. Destructive results in terms of loss of individual and national confidence will have been profound, to say nothing of unemployment, a lagging science base and loss of educational improvements. Youth both in America and the United Kingdom are learning more about real daily lessons in political failure than anything their textbooks can provide.

Modern concepts cannot be taught using out-of-date methods and subject matter. The failure to implement a technology preparation system in schools will produce a long-term result in the growth of whole generations unschooled in fundamental technological principles.

In the haste to develop new technologies, we have not paused long enough to decide what this means at a human level. The space frontier is a concept, not a place.

TOM BECKER
Olivette, USA

CORRESPONDENCE

The Martian Calendar

Sir, I read Thomas Gangale's article on a Martian calendar (***Spaceflight***, July 1988, p.278) with interest, but I must admit some surprise at his, and the other authors he mentions, deference to the custom of a seven day week. I believe that this is an unnecessary constraint on the development of a Martian calendar.

Let us take a closer look at the "week". The origin of the seven day week is lost in the mists of time but was probably chosen as a convenient quarter of the Lunar month, itself a convenient and visible measure of time. The Greeks changed from a 10 day week to seven days and the Romans from eight to seven at about the time of Christ.

The adoption of the seven day week by major religions ensured its survival until now when instant communications will ensure its survival by allowing us to conduct our business at the same time as each other.

This last point would not hold for dealings between Earth and Mars as the longer Martian day would cause their week to drift in relation to Earth's.

From a psychosocial point of view, anyone who has had a job that dispenses with the seven day week in preference to a more convenient "week" (researchers in the field, long term shift workers etc), will probably agree that it is soon forgotten and not even missed; and this is after a lifetime of indoctrination.

If we accept that the seven day week is not sacrosanct, it becomes easier to develop a convenient calendar. Imagine how easy it would be to keep track of the date if we were to use a 10 day week. In deciding on a new "Week" we must remember that if the colonists found it inconvenient, they would soon start to ignore it. The new week would have to be of a sensible length to make it easy for people to keep a mental track of it, say four to 12 days. To save confusion the length of the week must also be constant week to week. After all how many of us manage to remember to advance the date on our wrist watches at the end of each 28 and 30 day month, or advance them for Summer Time! You could get away with one short week at the end of the year.

In reality the length of the Martian week finally adopted by the colonists may end up having more to do with the practicalities of running their outpost than with any preplanned calendar, never mind how well thought out, as the proposed Darian calendar clearly is.

GETHIN BERMINGHAM
St. Davids, Wales

Sir, I have yet another Martian clock and calendar system for Thomas Gangale to add to his collection of "Lost Calendars of Mars" (***Spaceflight***, July 1988, p.278). I am writing a science fiction novel in which the calendar of the original settlers has no "months", and is divided up into 95 numbered seven-sol weeks, with four seasonal holidays outside the weekly calendar, for a total of 669 sols per Martian year. Since the correct value is 668.59906 sols per year, a holiday is dropped every 2.5 years. This calendar would track the seasons on Mars for over 1000 Martian years (about 2000 Earth years).

Instead of slowing down a Terran clock by 3 per cent, the scientists insist that a Mars second equal an Earth second. As a result their Martian day (sol) has 24 Martian hours of 3698 seconds, divided up into 86 Martian minutes of 43 seconds (43 is prime) for a total of 88752 seconds per ephemeris sol, 23 seconds less than the average physical sol. Terrible, but the best I could do once my scientist characters insisted that a second must be a second.

There *must* be a better clock system that maintains equality between the Martian second and the Earth second.

ROBERT L. FORWARD
Reay, Scotland

Microspacecraft

Sir, Readers of the article "Science Seeds" (***Spacecraft***, April 1988, pp.152-153) proposing electromagnetically-launched small scientific spacecraft may be interested to learn that the USA's Strategic Defense Initiative (SDI) is already yielding the technology to build these spacecraft.

The Hughes Company has produced a mini-vehicle, of just 3 kg weight, under the SDI LEAP (Lightweight Exoatmospheric Advanced Project) programme. The 14 in long, 8 in diameter LEAP vehicles were originally designed to be launched by electromagnetic methods but the technology is not yet perfected in time for SDI and, as a consequence, chemical propellants are being utilised. However, electromagnetic rail guns have been demonstrated successfully by groups at Massachusetts Institute of Technology (MIT) under Professor Gerard O'Neill.

P.J. PARKER
Newcastle, Staffs, UK

Satellite Programs

Sir, In the July 1988 issue of ***Spaceflight*** a letter was published from Nico Vermaas asking where he could find some satellite programs, and you suggested the USA. There is in fact a large number of programs published by AMSAT-UK and details can be obtained by sending an SAE to: The AMSAT-UK, 94 Herongate Road, London E12 5EQ.

JOHN C. FAIRWEATHER
Woking, Surrey, UK

Gemini Space Capsule

Sir, in response to Peter O. Johnson's query as to the whereabouts of the Gemini 2 space capsule (***Spaceflight***, June 1988, p.255), as of two years ago it was on display at the Air Force Space Museum at Cape Canaveral, Florida. Its heat shield clearly showed the cuts made as part of the MOL test as well, I believe, of some core samples cut for general testing.

The space museum is located at Cape Canaveral's complex 26, from which pads Explorer I and the two manned Mercury suborbital tests were launched, as well as some of the early Moon probes. A variety of rockets and other hardware are on display.

The museum's operating schedule is somewhat flexible; the complex is within site of NASA's Delta launch complex and thus is shut down when operations are underway.

Although the site has been declared a historic one, I believe, the museum seemed woefully underfunded during my visit. Some of the gantries were in need of repair and the museum was being staffed by retired Air Force members, who volunteered their time.

LARRY HOJO
Maryland, USA

Sir, I was pleased to see the letter from Peter O. Johnson which recalled the double flights of Gemini 2. In answer to his question on the fate of the spacecraft, Gemini 2 is on display in the Air Force Space Museum at Cape Canaveral Air Force Station. It can be seen, (complete with the very obvious hole in the heat shield), by taking the Cape bus tour which leaves the Spaceport USA visitor's centre. The Museum is also the location of the pads from which Explorer I and both Alan Shepard's and Gus Grissom's Mercury-Redstone flights were launched.

JACK B. LYLE
Florida, USA

43rd ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the 43rd ANNUAL GENERAL MEETING of the BRITISH INTERPLANETARY SOCIETY Limited will be held in the Society's Conference Room at 27/29 South Lambeth Road, London, SW8 1SZ on 17 September 1988 at 12 noon precisely.

Attendance is restricted to Fellows of the Society. Admission is by ticket. Those wishing to attend must apply for tickets not later than 10 days before the date of the meeting.

AGENDA

1. To receive the Report of the Council on the Society's Affairs for the year to 31 December 1987 (see p.358).
2. To receive the Society's Balance Sheet and Accounts for the year ended 31 December 1987 and the Auditors Report thereon (see p.362).
3. To appoint Auditors and determine the method of fixing their renumeration. The present Auditors have expressed their interest in continuing in Office.
4. To propose a SPECIAL RESOLUTION:-
   (a) That Clause 60 of the Articles of Association of the Society be amended to read 60 (a).

   (b) That a new Clause to be numbered 60(b) be inserted, to read as follows:-

   (60b) The Executive Secretary shall be charged with the duty of creating and maintaining in proper condition Society and Library Archive Collections, provided that no item designated by the Council as forming part of the Society's Archival Collection shall be sold or otherwise disposed of without the prior approval of a Resolution to be passed by not less than 75% of the vote of the Fellows of the Society, such Resolution to be decided by a poll taken by postal ballot of the Fellows of the Society only in such manner as the Council shall direct.
5. To elect four Members of the Council of the Society. In accordance with Article 43. The following Members of the Council will retire at the meeting:

   G.W. Childs
   Dr. R.D. Gould
   Capt. C.R. Hume
   Dr. L.R. Shepherd
   G.M. Webb

   If the number of nominations exceeds the number of vacancies, election will be by postal ballot in accordance with Article 44. The final date for the receipt of ballot papers will be 31 January 1989.
6. General Discussion.
7. Closing remarks by President.

By Order of the Council
L.J. CARTER
Executive Secretary

A Fellow who cannot be personally present at the meeting may appoint by proxy some other person, who must be a Fellow of the Society, to attend and vote on his behalf, subject, however, to the proviso that a proxy cannot vote except on a poll.

HQ Building Repairs

Members are advised that facilities at the Society's HQ are at present much reduced pending completion of repair work on the building's interior. It has been our custom to make every effort to accommodate informal visits by members to the Society's HQ, particularly by those from afar who find themselves in the London area, but in the circumstances we are obliged to ask for such visits to be deferred to a later date. In particular, the library will remain closed during this period and its scheduled opening on the first Wednesday of September has been cancelled.

Good progress by our building contractors with renovation of the exterior structure has been made in recent months. The nature of this work was reported in Society News in January and May. The front of the building is now clear of scaffolding and the roof has been renewed. The improved outward appearance of the building is a welcome sight but is misleading as much work is still in hand at the rear and in the interior as mentioned above.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Subject to space being available members may also apply for a ticket for one guest.

30 Sept – 2 October 1988 — Conference

SPACE '88

Major weekend space conference, including varied programme of lectures and full social programme.

Venue· White Rock Theatre, Hastings, Sussex, UK

Registration
Forms and detailed programme are available from the Society by sending 20p stamp or international reply coupon.

2 November 1988, 7-8.30 p.m. — Lecture

UK INVOLVEMENT IN SATELLITE NAVIGATION

J. K. Fellows (*British National Space Centre*)

Members and their guests only. Please apply for admission tickets in good time enclosing SAE.

15 November 1988, 10-4.30 — Symposium

EXTENDING THE SPACE INFRASTRUCTURE

The reports of the National Commission on Space and Dr. Sally Ride have paved the way for a new innovative space policy in the United States. It encompasses the setting up of bases on the Moon and manned exploration of the planet Mars The purpose of the symposium is to encourage and review American proposals and possible European contributions.

The symposium covers the following subjects:
- Infrastructure planning
- Orbital transfer systems
- Geostationary operations
- Lunar transportation system
- Lunar bases
- Planetary exploration systems
- Exploitation of the solar system.

Offers of Papers are invited
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms and other details are available from the Society. Please enclose SAE.

30 November 1988, 8.30 p.m. — Visit

SCIENCE MUSEUM

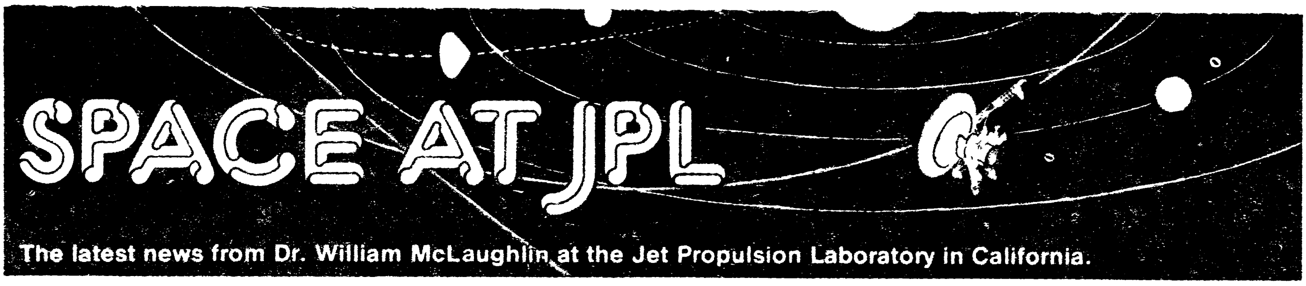
A special visit of Society members to the Science Museum in South Kensington The programme will provide an opportunity for a leisurely view of the Space Gallery and to see vintage space film footage

The fee will be £6 00 per member to cover the cost of a buffet with wine which will be provided

Advanced registration is necessary as the party will be limited in number. Guests will be allowed if space is available Forms are available from the Executive Secretary

LIBRARY OPENING

The Society Library is open to members on the first Wednesday of each month (except September) between 5.30 pm and 7 pm Membership cards must be produced



Supernova Observations

Last December a scientific payload descended in the early morning into a remote point of Western Australia's Gibson Desert. At the heart of the equipment was a high-resolution gamma-ray spectrometer fresh from a balloon flight which started 1000 km to the east in Alice Springs; the elevation provided by the balloon greatly reduced the blocking of gamma rays by the Earth's atmosphere. Already 4.5 hours of data taken at a height of over 39 km had been telemetered to a team of investigators from JPL – data which would add one more element to the emerging picture of the nearby supernova that exploded 286 days earlier.

"Nearby" is a relative term. The supernova, labelled SN1987A, was located in the Large Magellanic Cloud, an irregular satellite galaxy to our own, about 160,000 light years distant. But during the modern era, with its arsenal of multispectral, high-resolution instrumentation, no supernova had appeared sufficiently close to Earth for detailed study. SN19817A made up for that lack.

Dr. William A. Mahoney of JPL and his team of investigators designed their balloon experiment to measure accurately the flux of gamma rays at various energies that were being emitted from the supernova. Electromagnetic waves are conventionally classified into several regions based upon their wavelengths, the shorter wavelengths having higher energies. Adjacent to the visible region, at its shorter-wavelength (blue) end is the ultraviolet region. Continuing down in wavelength and up in energy, one next encounters x-rays, then gamma rays. The longer-wavelength (red) end of the visible domain merges into the infrared, followed by submillimeter and radio waves. Observations across the electromagnetic spectrum and detection of neutrinos contribute to understanding the nature of a supernova – the most violent event in the universe.

One of the triumphs of twentieth-century astrophysics is the development of quite good theories of the origin, internal processes, and life histories of stars. Stars are better known objects than, for example, the galaxies in which they are imbedded.

Thus, with some confidence astrophysicists could describe the properties and history of the star which exploded, a faint object previously catalogued as Sanduleak (SK)-69 202. The pre-supernova star was classified as a blue supergiant (a surprise since it had been thought that this kind of supernova, type II, only arose from red supergiants) and was about 10 million years old. The Sun will last for a total of about 10,000 million years before transitioning to its old-age phase as a white dwarf. Rapid evolution is characteristic of massive stars, and SK-69 202 was about 20 solar masses at birth.

In order to appreciate the significance of gamma ray emissions in the events comprising a supernova, it is useful to review, very briefly, some facts about the evolution of massive stars like SK-69 202. A presentation-in-depth is available to the general reader in Frank Shu's excellent textbook, *The Physical Universe* (University Science Books, 1982), and a synopsis by S.E. Woolsey and M.M. Phillips of the findings to date concerning SN1987A, also suitable for the general reader, is contained in their paper in the May 6, 1988 issue of *Science. Sky and Telescope* magazine periodically presents topics of interest in the ongoing story of the supernova.

A star originates from the gravitational collapse of a portion of a cloud consisting of hydrogen with an admixture of helium and traces of heavier elements. Heating from the continued crush of self-gravitation eventually becomes intense enough to initiate nuclear reactions. For about 90 per cent of the star's life, hydrogen is converted to helium in the stellar core through nuclear fusion, and the mass which is converted to energy in this reaction works its way out to the surface and is radiated into space; the star shines with a colour indicative of its surface temperature. The energy generated by the star suffices to balance its tendency to collapse even further under self-gravitation.

The conversion of hydrogen to helium eventually results in the formation of an all-helium core for the star. In the case of SK-69 202, this core was in place about 1 million years ago with a bulk of approximately six solar masses.

The star must now find new strategies to stave off gravitational collapse – it does this by yielding slightly to gravitational pressures and heating up through modest contraction of the helium core. A new set of nuclear reactions is enabled, and helium, the "ash" from the burning of hydrogen but now the fuel, begins to be converted by fusion to carbon and oxygen. Hydrogen continues to burn in a shell around the core.

A number of elements – hydrogen, helium, carbon, neon, oxygen, silicon – serve in succession as fuel at the core of the star, each (except hydrogen) the result of nuclear transformation of its predecessor. As a result of this process, the star develops an onion-skin structure with the layers consisting of unburnt portions of former cores. The successive phases of burning are completed at ever increasing rates and temperatures until the final stage, when silicon is converted to iron, lasts only a few days and takes place at a temperature of 3,500 million degrees. By contrast, the hydrogen-burning phase proceeds at a core temperature of about 40 million degrees.

However, the nuclear reactions involving iron *consume* energy. Thus, the iron core is the end of gradual evolution for a massive star and presages gravitational collapse to either a neutron star or, for very massive objects, a black hole (as previously indicated, less massive stars end up as white dwarfs, a third option for stellar senescence). For SK-69 202 the transition to SN1987A was about to begin.

The collapse of the iron core to a neutron star (or black hole) yields what is called a type II supernova. Other stellar explosions, such as novae and type I supernovae, are associated with a variety of processes, including mass transfer between members of a binary system.

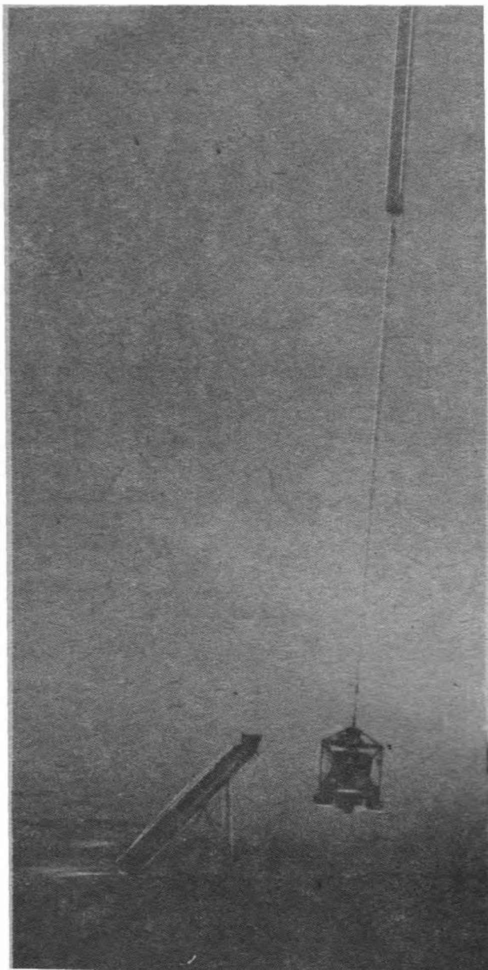
The final collapse for SK-69 202 was so rapid that in a few tenths of a second an interior structure the size of the Earth was converted to an object with a 50 km radius; speeds up to one quarter that of light were attained. A flood of neutrinos, massless particles (except in some recent theories which ascribe a slight mass to them) travelling at the speed of light, was squeezed out of the core and detected on Earth. The energy invested in this flux of neutrinos during the first second of collapse exceeded by a factor of 100 the entire energy output expected from our Sun during its 10,000-million-year life time and provided direct evidence for the collapse of the core.

Collapsing stellar material outside the just-formed core, which was in the process of rebounding, was brought to

a sudden halt. As a result, a powerful shock wave was propagated through the star, blowing its outer layers into space. It was this event that led to the discovery, 160,000 years later, of SN1987A by Ian Shelton at the Las Campanas Observatory in Chile.

If the supernova had been powered only by the energy associated with the shock wave, the observed luminosity would have peaked and started to fall rapidly after about 40 days. Instead, the luminosity climbed and reached a maximum 85 days after the initial explosion; then it began to decrease. The source of extra energy is linked to the production of a radioactive element by the explosion and the reason why Mahoney and his group sought gamma rays from their balloon.

Successfully launching an 800-foot balloon system requires intricate coordination. *NASA/JPL*



Supernovae are the source of basically all the elements in the Universe heavier than hydrogen and helium, which were produced from the Big Bang that began everything. We have seen how the elements up to iron were synthesised in the stellar core and distributed by the explosion into interstellar space, for incorporation into later-generation stars and planets.

Nickel-56 was created in abundance by the cataclysm: about 0.07 solar masses were produced by the shock wave passage. This particular isotope is unstable, and in a few weeks it had all decayed to cobalt-56, a longer-lived radioactive isotope. The radioactive decay of cobalt is the continuing energy source for SN1987A, and the rate of fading of the supernova faithfully tracks the rate of decay of the remaining store of cobalt-56.

When cobalt-56 decays (to iron), gamma rays are emitted. However, as expected, no gamma rays were detected in the first few months after the discovery of SN1987A; the expanding shell of intervening material from the outer layers of the star blocked direct observations as it absorbed the energy from gamma rays and re-radiated it at other wavelengths. The expansion of the shell with time decreased the amount of material along the line of sight, and in the summer and fall of 1987, first X-rays, then gamma rays were observed by teams from several countries using satellites and balloons.

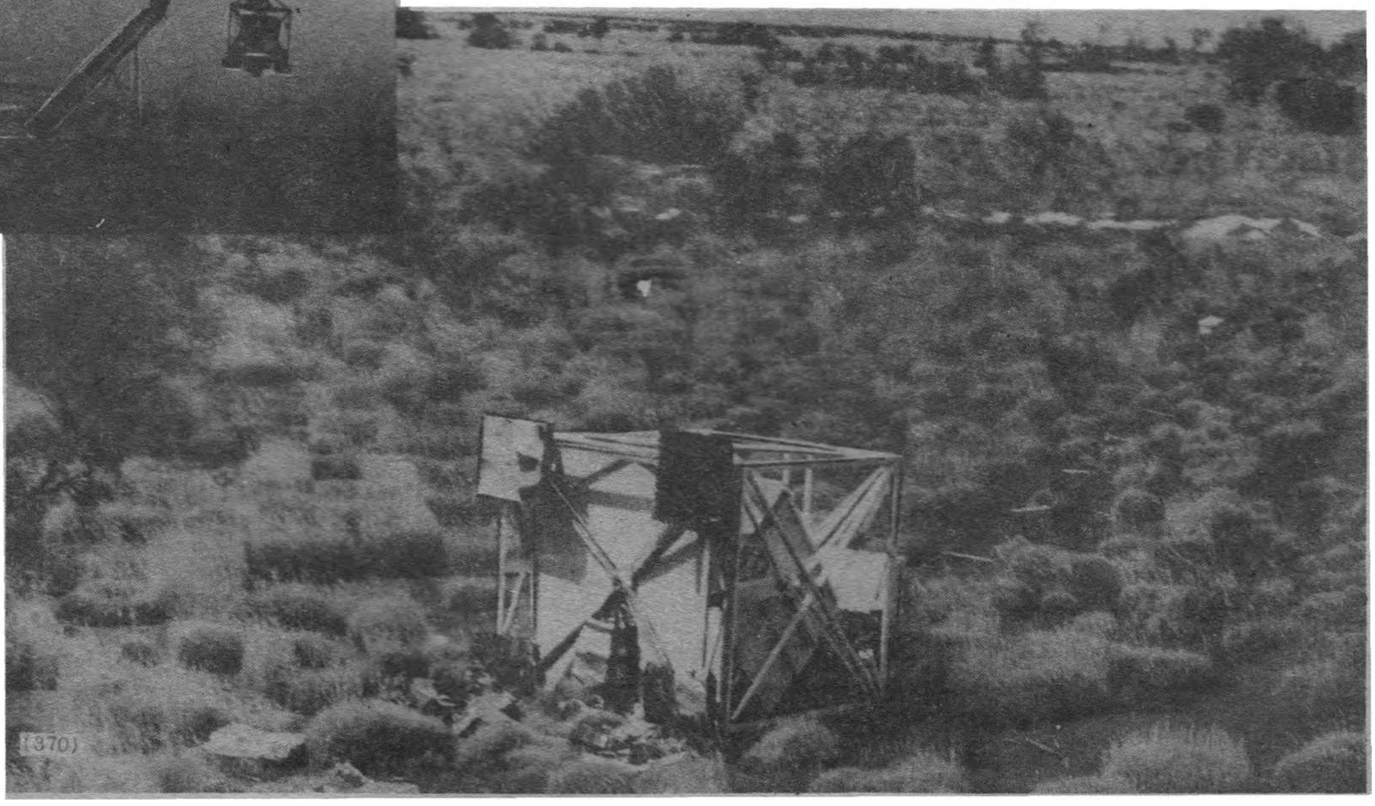
Mahoney said that despite the delayed observation of gamma rays, this radiation did arrive sooner and in larger amounts than predicted by computer models of the supernova. One possibility for this discrepancy is more thorough than expected mixing of the initial nickel into the expanding shell of the supernova, permitting the gamma rays to leak to space more readily.

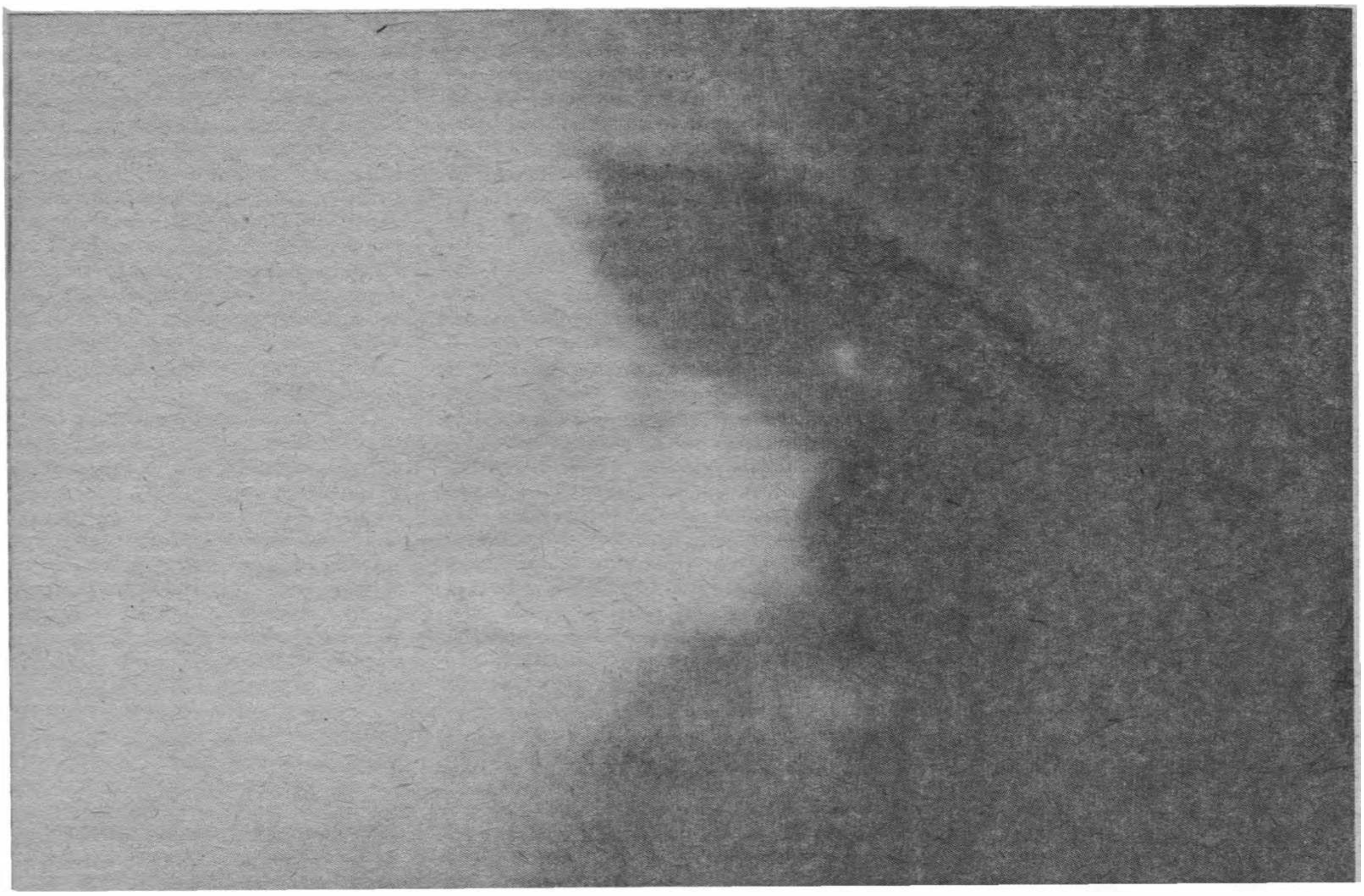
The success of Mahoney's team went beyond simple detection of gamma rays; the large germanium detector accurately converted gamma energy to electric signals allowing unique identification of the radioactive isotope. In addition, measurements of doppler shifting yielded velocity estimates for ejecta. Through this work, new constraints were provided for models of mixing within the supernova.

The gamma ray payload was successfully retrieved from the Gibson Desert but not without travail. A motoring expedition to the site failed, and recourse was had to a combination of helicopter and airplane. Launching the 800-foot balloon and gondola system had been even more difficult. Seventeen consecutive days were expended as launch holds were dictated by surface winds threatening to disrupt the long, flexible array. Finally, on the 18th day, release was accomplished and the balloon drifted to observing height.

The four and a half hours spent alternately observing the supernova and, for calibration, adjacent areas of sky, are representative of the extensive efforts that have gone into characterising SN1987A, an event whose consequences should influence astronomical thought for decades.

A gamma-ray spectrometer, after observing Supernova 1987A while suspended by balloon at a height of 39 km, was parachuted to Earth in Western Australia's Gibson Desert. *NASA/JPL*





The nucleus of Halley's comet was revealed by the flight of the European Space Agency's Giotto spacecraft, approaching to within 600 km on March 14, 1986.
Max-Planck Institut für Aeronomie

Cometary Chemistry

The Giotto spacecraft of the European Space Agency (ESA) made a dramatic approach to the nucleus of Comet Halley on March 14, 1986. Though buffeted by dust and, in consequence, wobbling slightly as it passed approximately 600 km from the nucleus, the tough machine managed to survive and return an unprecedented amount of scientific data. Despite the obscuring wrapper of cometary ejecta, the spacecraft's camera obtained exciting images of an elongated, very dark nucleus with surface features. Although the perilous traverse and the visual results dominate first impressions of the encounter, there is, of course, much more to be learned from the Giotto mission. We will examine some deductions concerning chemical conditions in Comet Halley.

The Astrochemistry Group at JPL was formed by Dr. Wesley Huntress, Jr. The group specialises in the chemistry of the interstellar medium (ISM), planetary atmospheres, and comets.

The ISM, as the name implies, consists of material lying between the stars. Mostly hydrogen, it also contains dust (composed of silicates and other materials) and numerous chemical species, our knowledge of which has grown rapidly in the last few decades with the discovery of additional elements, molecules, and complex organic molecules. The ISM is not homogeneously distributed; much of it is clumped into so-called Giant Molecular Clouds (with molecular hydrogen predominating), but the average density is only on the order of a few atoms per cm^3. The solar system and other stellar systems were formed as a result of the gravitational collapse of portions of the ISM.

Mona Delitsky is a member of the Astrochemistry Group. Her interests also include the chemistry of atmospheres in the outer solar system (refer to her paper on Neptune's large satellite Triton in the May 1987 issue of *Icarus*), but we concentrated on discussing the chemistry of Halley's comet as revealed through analysis of Ion Mass Spectrometer (IMS) data from Giotto.

Chemical reactions in the Earth's atmosphere – see, for example, those described in "Ozone Chemistry" in the March 1988 edition of this column – largely involve interactions between electrically neutral molecules. In the less dense, lower pressure environment of the ISM or comets, ions (atoms or molecules with a net positive or negative electrical charge) play an important role. Giotto's IMS is able to measure the ratio of mass-to-charge for particles which it processes, and a description of the experimental configuration and measurements has been published by H. Balsiger, *et al.* in the May 15, 1986 issue of *Nature*.

A general computer model, applicable to comets, planetary atmospheres, and the ISM, was employed by the JPL group to analyse the Giotto data and obtain a better understanding of the chemistry of the coma (material surrounding the nucleus – the third component of a comet is the tail). Hundreds of different chemical reactions, deemed relevant to cometary environments, are contained in the model. These include reactions between chemical species and between the species and solar photons. Each reaction is accompanied by a rate constant which characterises the speed of the reaction in converting reactants into products. The values for rate constants were obtained directly from the chemi-

cal literature, reflecting laboratory measurements.

Chemical abundances in the coma are regulated by the physical environment as well as chemical considerations *per se*. Thus, the model requires specification of the amount of solar energy incident to the system and the gas dynamics expected to be applicable to the region. The solar flux was defined accurately from space measurements made by other investigators, including some made on the day of the encounter by the Solar Mesosphere Explorer satellite. Parameters characterising gas dynamics were supplied by the results of other investigators for the Giotto encounter.

The effectiveness of solar radiation on the system's behaviour is modulated by the opacity of the coma. The Astrochemistry Group included absorption due to water molecules and will in the future incorporate the shielding effects of cometary dust.

Since the investigation was focused on determining the amounts of methane (CH_4) and ammonia (NH_3) in the coma, only a subset of the Giotto IMS data had to be analysed: those ions with masses between 12 and 19 atomic mass units (the hydrogen atom has mass approximately equal to one of these units).

It turned out that about 70 of the hundreds of reactions in the model were relevant to determining the methane/ammonia chemistry of Halley's comet. The output of the model is the abundance of various chemical species as a function of distance from the nucleus.

Results, reported in the December 1987 issue of *Astronomy and Astrophysics*, showed that the methane and ammonia proportions differed from the amount of those gases contained in the atmospheres of the outer planets and also were unlike the proportions seen in the interstellar medium. Amounts of methane and ammonia relative to H_2O in the nucleus are a few per cent for each. The ratio of methane to carbon monoxide (CO) shows that the partitioning of carbon between the two chemical species is different from that in the atmospheres of the outer planets and the ISM. These results may yield insights concerning the origin of comets.

Further studies of the Giotto data are planned for chemical species of higher masses, and the group would also like to analyse data from the ICE penetration of the tail of Comet Giacobini-Zinner in 1985.

Delitsky will have a chance to test at first hand her analysis of Triton since she has recently joined the Voyager project as a part-time member of the Radio Science Team. Quoting from her *Icarus* paper: "Perhaps Voyager 2, turning its cameras on Triton in 1989 will see plains of white and coloured organic deposits and, maybe, the glint of a distant sun reflected off a calm nitrogen sea."

Juggling Numbers

Number entered early into Western views of the structure of the Universe. The first preoccupation of Greek natural philosophers was with identifying the substance lying at the basis of the world. Thus, Thales proposed water, Anaximenes air, Heraclitus fire, and Pythagoras number. No written works of Pythagoras, born in the sixth century BC on the island of Samos, have survived, but classical traditions identify an important root of the Pythagorean confidence in number as growing from the discovery that the lengths of strings bear a simple numerical relationship to intervals on the musical scale. Mixed with their scientific and mathematical researches, Pythagoras and his school speculated on more mystical aspects of number. The suspected conjunction of science and mysticism, "numerology", has clouded to the present day those researches that are initiated or rest upon numerical premises. Nevertheless, this approach has proved fruitful in the history of science, and we will examine some of its mechanisms and results.

The planetary system has provided fertile ground for speculations based upon the symmetries of number and geometry.

Johannes Kepler's (1571-1630) three laws of planetary motion are among the first "laws of nature" in the modern sense and were a key factor in the development of Newton's dynamical system. However, throughout his entire career Kepler was motivated by numerous mystical convictions. For example, he harked back to Pythagoreanism with the belief that musical harmonies were an important factor in planetary motions. The scientific output of Kepler was made possible by his scrupulous attention to observational data.

Another example is furnished by the Titius-Bode law, which appeared in 1772 as a simple numerical recipe for obtaining the distances of the planets from the Sun: $a_n = 0.4 + 0.3 \times 2^n$. Here a_n is the mean distance (semi-major axis) of the nth planet (n = minus infinity for Mercury, n = 0 for Venus, n = 1 for Earth, etc.) and is measured in astronomical units (distance from Earth to Sun).

The credibility of this empirical formula was strengthened by the discoveries of Uranus (1781) and the first asteroid, Ceres (1801), which fell in the locations predicted for the values n = 3 and n = 6, respectively. Undoubtedly, these two favourable instances provided the motive force that has kept the Titius-Bode expression a subject of discussion to the present day in a way that a mere *a posteriori* rendering could not have done. However, the Titius-Bode values for n = 7 and n = 8 overestimate the distances of Neptune (discovered in 1846) and Pluto (1930).

Much of the later history of the Titius-Bode law has been a series of attempts to modify the formula to account for the failures with regard to Neptune and Pluto and to extend its applicability to include satellite systems. A modification in 1913 by Mary Adela Blagg (1858-1944) gave a good fit for Neptune, accommodated Pluto rather well when it was later discovered, and supplied reasonable interpretations for the satellite systems of Jupiter, Saturn and Uranus. Your correspondent has even entered the lists with a paper in the April 1979 *Fibonacci Quarterly*.

An alternative to seeking modifications of the Titius-Bode law is to deny the existence of failure. For example, Pluto could be dismissed as too small to lie in the domain of the Titius-Bode law – a mere appendage to the series of gas giants, Jupiter through Neptune, – or, as some have tried, argue that it is an escaped satellite of Neptune.

Neptune should lie at 38.8 astronomical units according to the formula, but its actual mean distance is approximately 30.1. One could treat this discrepancy of 8.7 astronomical units as not too severe to deny meaning to the formula, or a physical explanation could be sought. One such explanatory hypothesis arises by considering the origin of the Oort cloud of comets which is believed to surround the solar system, at a great distance from the Sun. Two theories of origin for this warehouse of comets are currently popular: (1) the Oort cloud condensed in its current location from the primitive solar nebula – by processes analogous with those that produced the planetary system from the solar nebula, or (2) comets originated in the domain of the outer planets and were ejected by gravitational encounters with Uranus and Neptune to form the present day Oort cloud.

It is not difficult to calculate what total mass of comets had to be ejected by Neptune to subtract enough energy from that planet to move it inward from 38.8 to 30.1 astronomical units – energy gained by the comets is assumed to be lost by Neptune. The answer turns out to be a total cometary mass that is equal to a few times the mass of the Earth, perhaps a not unreasonable number from a cometary viewpoint. Of course, this calculation proves nothing, but it is in the spirit of numerical exploration and could prove relevant if theoretical reasons for believing the Titius-Bode law were ever to be adduced.

While the final judgement has not been pronounced on the status of the Titius-Bode expression, a successful numerical hypothesis is contained in the history of spectroscopic science. Empirical formulae were developed in the late nineteenth century by the Swiss mathematician and physicist Johann Balmer (1825-1898) and others to describe the location of atomic spectral lines. It was not until the advent of quantum physics that these formulae received theoretical justification (for a large number of examples of numerical experimentation in physics see the discussion by J.D. Barrow and F.J. Tipler in *The Anthropic Cosmological Principle*, 1986, Chapter 4).

The well-known physicist Sir Arthur Stanley Eddington (1882-1944) devoted a large amount of time trying to develop a fundamental theory which would allow one to calculate the numerical values of the dimensionless numbers of physics. A simple example of a dimensionless number is the ratio of the mass of a proton to the mass of an electron (this is approximately equal to 1836); the dimensions of mass cancel, and we are left with a pure, dimensionless number.

Eddington believed that the number N of particles in the Universe exerted a strong influence on many of the values of these quantities. While most of the dimensionless numbers in question cluster within a few orders of magnitude of 1, there are clusters near the large numbers 10^{40} and 10^{80}. He hypothesised that N, which is equal to about 10^{80}, governed the values of the dimensionless numbers close to these two large values while not explicity entering into the determination of the cluster near unity.

Eddington's speculations have not led to much of note in present-day physics, but another famous physicist, Paul Dirac (1902-1984), has pursued a related vein of speculation that is still under investigation.

Like Eddington, Dirac focused on the very large dimensionless numbers of physics. But unlike Eddington, who thought that these large dimensionless numbers must be tied to the large number of particles in the Universe, Dirac tied the large numbers to one another through his Large Numbers Hypothesis. Roughly speaking, this hypothesis says that if two of the dimensionless large numbers of physics are nearly equal, one can set their corresponding expressions equal to each other and obtain a physically meaningful relation.

An example will illustrate the principle. The ratio of the age t_0 of the Universe to the time it takes light to cross a region of atomic dimensions (the latter time is defined by a simple expression involving three physical constants: the electric charge of an electron, the mass of the electron, and the speed of light) is approximately equal to 10^{40}, a large dimensionless number. Similarly, the ratio of the electric force between a proton and an electron to the gravitational force between these two particles is a dimensionless number close to 10^{40}. Equating these two expressions, by Dirac's hypothesis, yields a (valid?) relation between the six physical constants involved in the definitions of these two numbers (four constants, as listed above, in the first ratio; the mass of the proton and the Newtonian gravitional constant are additionally employed in the second ratio).

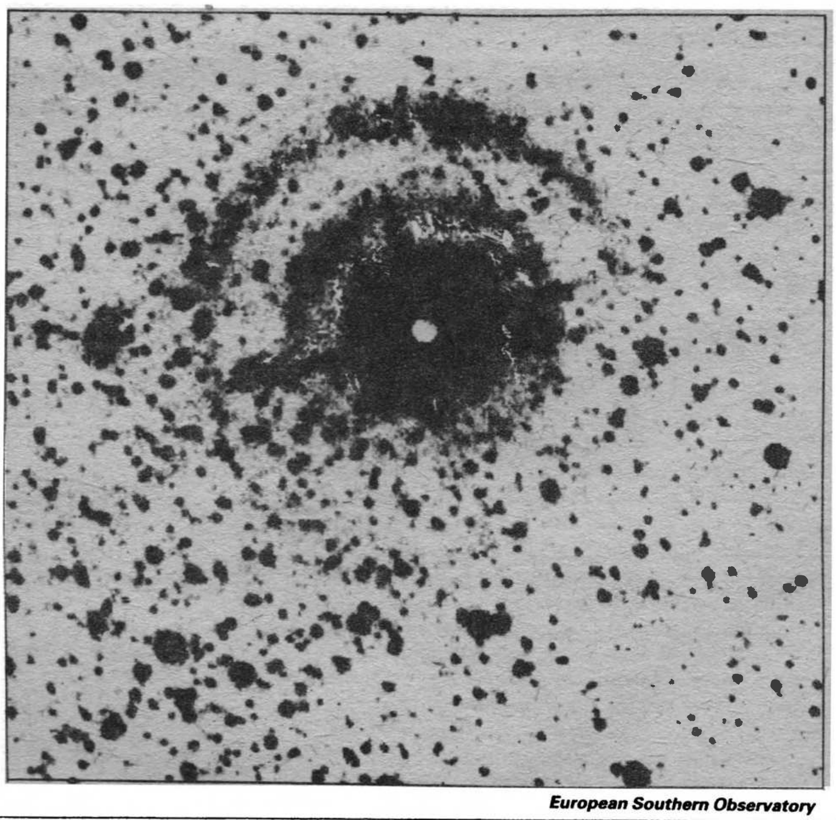
The preceding example serves to do more than illustrate the Large Numbers Hypothesis. Dirac used it as a point of departure for an interesting speculation in gravitational theory. Newton's constant of gravitation, commonly denoted by G, appears in the denominator of the second of the

Light Echo from Supernova 1987A

A double light echo from Supernova 1987A in the Large Magellanic Cloud (LMC) was observed on February 13, 1988 with the European Southern Observatory (ESO) 3.6 m telescope and the EFOSC instrument (observer: Dr. Michael Rosa). The light echoes are reflections in interstellar clouds in the LMC of the light from the bright supernova explosion, first observed on February 23, 1987.

The light echoes are seen as two concentric rings around the overexposed image of the supernova itself. The outer ring, which has a radius of ~ 50 arcseconds, is strongest towards North, but can be followed all the way round. The inner ring has a radius of ~ 30 arcseconds. Note that the "cross" extending from the image of the supernova is an artifact from the telescope optics.

This computer-enhanced photo was obtained by a CCD detector behind a narrow optical filter at a wavelength near 470 nm, thereby suppressing the light from interstellar nebulae in the LMC in order to improve the visibility of the light echoes. For the same reason, the photo is here reproduced as a negative (black stars on a light sky).



European Southern Observatory

expressions defined above, while the age of the universe appears in the numerator of the first expression. Assuming that the other four constants in the expressions are indeed constant, this implies, by elementary algebra, that the "constant" G actually decreases in value as the Universe ages! That is, Dirac claimed his Large Numbers Hypothesis implied a weakening of the force of gravity with time.

The weakening of gravity with time would have profound cosmological consequences, and numerous subsequent investigators have advanced gravitational theories where G varies with time and searched for experimental tests of the hypothesis. See, for example, the piece on general relativity in the May 1988 edition of this column.

The last topic for discussion is in some ways the most unusual. It permeates everyday life as well as physics and, in my experience, has rarely failed to elicit surprise from the uninitiated.

Gather a list of, say, the street addresses of 100 of your acquaintances. Count how many of these addresses begin with the digit "1", how many begin with "2", then "3", and, in this way, continue on up to counting how many of these addresses begin with the digit "9". In all likelihood, the number of addresses beginning with the digit "1" will exceed those beginning with "9". Moreover, the 1-class should contain approximately 30 members and the 9-class only about 5 members. The seven intervening classes (first digits "2" through "8") should have intermediate counts of members, declining in size as the first digit increases.

In 1938, the American physicist Frank Benford pointed out the "law of anomalous numbers" and since then a rather large literature has been generated on "Benford's law" (once again the reader is exhorted to repair to his or her collection of *Fibonacci Quarterly* issues and, extracting the May 1984 issue, consult one of my papers: on the mathematics of the Benford phenomenon). The general formulation of Benford's law relates to the frequencies of the first nonzero digits of certain sets of numbers (street-address lists furnishing one example). These numbers do not have to be integers, for example, the first nonzero digit of 0.00214 is "2" while that of π is "3". Benford's law says that the frequency of "1" as a first digit will be approximately 0.301, that of "2" approximately 0.176, and, more generally, the frequency of the digit $K > 0$ as a first digit can be calculated by taking the (base 10) logarithm of $1 + 1/K$. The surprise is that these frequencies are not all equal with a value of 1/9.

What are these "certain sets" of numbers to which Benford's law applies? If all of your 100 acquaintances live in the same flat, the street-address example will fail to conform in a Benfordian fashion. Also, the weights, in pounds, of a collection of typical American adult females will fail to conform; most of these weights would begin with the digit "1", with few other values of first digits represented.

Nevertheless, a large variety of data do fit the Benford pattern. Open a reference book and tabulate first-digit frequencies for a list of the lengths of the world's rivers, or the first digits of the areas of lakes. The choice of units: miles, kilometres, square feet, acres, will not affect the results. The data do not have to be homogeneous: nonzero first digits of an assortment of miscellaneous physical constants, taken from a handbook, will usually obey Benford's law. The upright of character will vow never to win a monetary bet from their friends by pulling out an almanac and counting first digits in some list of numbers (a just punishment of such an attempt would be to hit upon a list of the dates of significant events in the ninth century).

Granting that the Benford phenomenon is a surprising fact concerning the behaviour of many classes of numbers, what might explain this fact? Many explanations have been devised over the years, none of them too convincing. Benford himself left it at the supposition that nature tends to be logarithmically structured. Perhaps this is not far from the truth. Sir Harold Jeffreys in the *Theory of Probability* (1961) argues that the most logical probability law for a list of positive numbers, about which nothing else is known, is a certain expression which would imply Benford's phenomenon (Jeffreys does not seem to have been aware of Benford's law).

The art of juggling numbers has, on the whole, been of benefit to the physical sciences. It escapes the taint of numerology when utilised as an exploratory device which could lead to the discovery of physical causes. The source of the effectiveness of numerical speculation is not easily identified, but it may spring from the activation of the powerful human urge to solve a puzzle: why do the numbers behave thusly?

Extending The Space Infrastructure

The Space Shuttle and the NASA programme to develop a Space Station mark the first steps in the construction of the infrastructure in space. This in-orbit infrastructure will be analogous to the infrastructure that supports society on the ground; that is roads, railways, power utilities, universities eta.

There is much more to be added to the space infrastructure to be an effective base for the foundation of a complete space economy. The next stages have been outlined by the National Commission on Space report and the Ride report. These pave the way for exciting new initiatives in Western space policy, including the establishing of a permanent base on the Moon and the landing of men on Mars.

The BIS is holding a symposium on the 15 November at the Society's Conference Room to discuss these subjects.

Papers to be presented include:

1. Goals for an Expanded Infrastructure: Are We Too Late?
   C.M. Hempsell
2. An Input-Output Model for the Space Economy of 2050 AD
   R.C. Parkinson
3. Earth Moon Transportation Models
   D.J. Salt
4. The Use Of Pallets On the Space Station
   C.H. Martin

Offers of further papers are invited. Authors wishing to present papers should contact the Executive Secretary.

Registration forms are available from the Society. Please enclose a stamped addressed envelope.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Front Cover: A close-up of the shuttle orbiter Discovery taken in the Vehicle Assembly Building prior to its mating with the **External Tank.** A special nine-page feature on the Space Shuttle begins on p.385.

Shuttle Main Engine Story

Failure of the main engines of NASA's shuttle Discovery to ignite during a test countdown on August 4, highlights this long-standing problem-area of shuttle technology. Much overshadowed since the Challenger accident by the attention given to the problems and re-design of the Solid Rocket Booster, the main-engine problems are now given a timely airing by *Harald Kränzel.*

The Space Shuttle Main Engine (SSME) is one of the most interesting systems of the Space Transportation System (STS). It is the world's most advanced liquid-fuelled rocket engine and is able to fly several different missions. Three of these engines are installed in the aft-compartment of each orbiter and power the Space Shuttle into Earth orbit.

During the first two minutes and 10 seconds of flight it fires along with two Solid Rocket Boosters (SRBs) which are attached to the sides of the huge External Tank (ET). After SRB-separation it burns alone for about 6½ minutes.

Twelve out of the 13 assembled SSME flight units have served to launch the four orbiters Columbia, Challenger, Discovery and Atlantis into orbit on 25 STS missions (see Table 1) before the tragic Challenger accident on January 28, 1986 caused NASA to temporarily halt the programme.

Some of these SSME engines have played a key-role in postponing and rescheduling STS-missions. The following is their story:

The Early Shuttle Flights

At the end of 1979 before launchings began a general welding problem was discovered. A large number of welds had been made using softer material than required. The first flight-engines 2005, 2006 and 2007 consequently had faulty welds which required repair at the Kennedy Space Center (KSC). All three engines had been through acceptance firings prior to the repair (normally three tests with 1.5, 250 and 520 seconds burning time) and then shipped to the National Technology Laboratories (NSTL), now named the John C. Stennis Space Center. Here a reacceptance firing was conducted for each engine, after which they were delivered back to the KSC for reinstalling into Columbia. Following this they were fired for 23 seconds in the Flight Readiness Firing (FRF) on February 20, 1981. The purpose of this test is to verify that all systems used to launch and fly an STS-mission are OK and it culminates in the firing of the three SSMEs without having a liftoff. Each new orbiter has to go through that procedure prior to its maiden flight. Concerning the orbiter Discovery and the forthcoming STS-26 launching NASA has said that because of all the modifications that have been made after the Challenger accident Discovery was to be treated as a new orbiter and an FRF would be necessary.

by Harald Kränzel

Although the first five missions of Columbia were flown with the above-mentioned engines, many parts had to be repaired, modified or replaced after each flight : the turbopumps and their blades, several valves, pipes, tubes and the nozzles.

The first four test flights were flown without real problems concerning the operation of the SSMEs. But one incident should be mentioned : during the ascent of the STS-3 mission, 31 seconds prior to Main Engine Cut-Off (MECO), the temperature readings of Auxiliary Power Unit (APU) No. 3 reached critical values and it had to be shut down by the astronauts. Five valves in each SSME, which regulate the liquid fuel flow, are hydraulically controlled by one APU. APU No.3 does this for SSME No. 3 (2005). The engines are programmed to lock the valves in position at the moment of loss of hydraulic pressure. This was at 82 per cent for engine No. 3, because the engines had been in a phase of thrust reduction prior to MECO. This event caused pilot Fullerton to look through the checklists to see whether this engine had to be shut down manually. There was no need to do this because a backup pneumatic helium system had done so satisfactorily. To maintain the 3g limit, the other two engines had to go through a different throttling procedure because of the locked engine No. 3.

The Challenger Problems

Real problems with flight-engines arose prior to the maiden flight of the orbiter Challenger : STS-6. The first FRF with engines 2011, 2015 and 2012 on December 18, 1982, lasting 20 seconds, showed two anomalies :

- a small crack, about 20 cm above the end of the nozzle that did not have any effect on the performance of engine No. 3.
- some high concentrations of hydrogen in the aft compartment of the orbiter that were too high for a safe ascent into orbit.

As the source of this hydrogen could not be located during post firing checks, a second FRF, highly instrumented, was conducted on January 25, 1983. Technicians were able to find a 3/4 inch crack in a tube on engine No. 1 (2011). NASA decided to replace it by engine 2016 which was outfitted with the low pressure oxidiser turbopump of engine 2011. After leak checks on engine 2016 also revealed a leak, engine 2017 was announced as replacing engine 2016. Preflight leak-checks on the two other engines 2015 (No. 2) and 2012 (No. 3) also revealed a crack on both in the same area as on 2016. This forced NASA to repair them at the KSC in order to get the engines ready to fly. Engines 2012 and 2015 were repaired and reinstalled into Challenger and as a precaution any measure, the same repair was made to engine 2017, although no such crack was found there. This engine configuration was flown successfully on missions STS-6, 7 and 8. After STS-8 engine No. 1 (2017) was replaced by engine 2109.

Orbiter Columbia, readied for the STS-9/Spacelab 1 flight, had been fitted out with three new engines (2011, 2018 and 2019). After this first Spacelab-mission various modifications were planned for this orbiter which freed its engines for use on other flights.

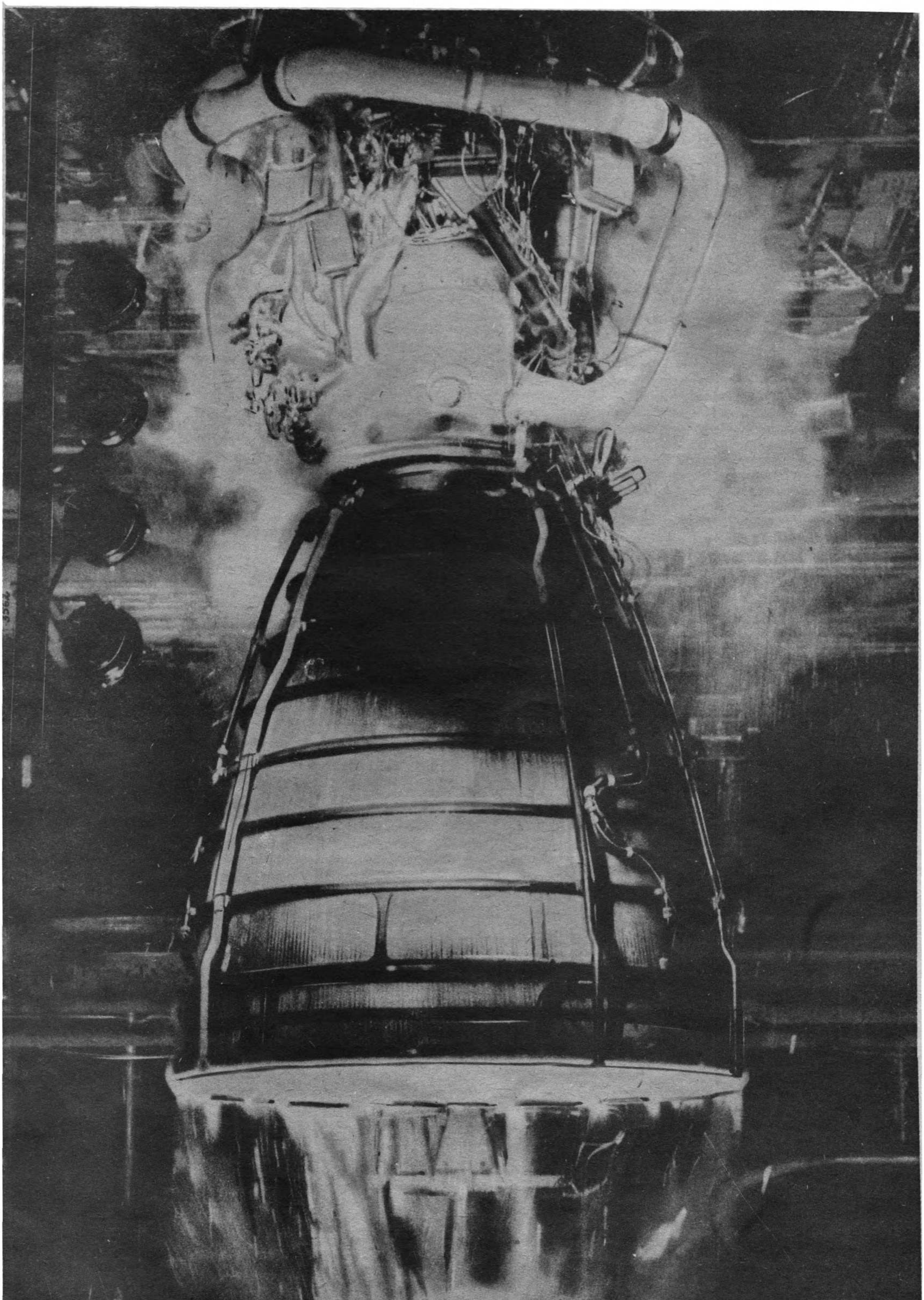
Following mission STS-41B inspection of Challenger's engine No. 2 (2015) revealed some corroded parts and it was therefore replaced by engine 2020.

Discovery Joins The Fleet: The Aborts

Prior to its maiden flight the orbiter Discovery went through an FRF on June 2, 1984, that lasted 18 seconds. Two of its engines 2021, 2018 and 2017 had previously flown on either Challenger or Columbia. Although the FRF was successful, post-firing inspections revealed delaminations of a heat-shield in engine 2021 which was therefore replaced by another Challenger engine : 2109. After resolving all problems the first planned Discovery mission (scheduled for June 25, 1984) ended with the first ever STS-launch-abort. The countdown went smoothly until T-6.6 seconds when the SSME-start sequence was in progress. But at T-0, Discovery did not launch as planned. Instead the orbiter still sat on the launch pad. What had happened? The onboard computers found that the main fuel valve in engine No. 3 was not working properly. Although the selected backup mode worked satisfactorily, no launch occurred because flight-rules dictate not to start a mission that already depends on a running backup system. Engines No.2 and No.3, which had already ignited, were shutdown by the computer while engine No. 1 never ignited. At T-4 seconds the countdown was halted.

A SSME undergoes a static test
Rockwell International

NASA decided to replace engine 2017 by engine 2021, the original No.1 engine. These three engines (2019, 2018 and 2021) powered Discovery into orbit on its first mission, STS-41D in August 1984. Following this engine 2021 was replaced by engine 2012 and



(379)

the same engine configuration was used by the orbiter Discovery five times (see Table 1). As two of Discovery's engines had been cannibalised from Challenger, the latter was given two new engines : 2023 as No.1 and 2021 as No.3. The same three engines then flew all missions until STS-51L although two aborts took place, namely

- the second STS-launch-abort and
- the first inflight abort.

The STS-51F-launch-abort was similar to the one of STS-41D with the difference that the main fuel valve in engine No.2 (2020) caused the abort and that the countdown was halted at T-3 seconds with the effect that by that time all engines had ignited. The first Abort To Orbit (ATO) was during the ascent of STS-51F (Spacelab 2). An erroneous reading temperature of a malfunctioning sensor in engine 2023 caused the onboard computers to shut down engine No. 1 after 5 minutes 45 seconds into the flight to prevent it from overheating. Ten seconds later Commander Fullerton started the first ATO, an abort mode that brings the orbiter into a safe orbit. As the temperature reading in engine No.3 (2021) also reached a high level, the astronauts made a computer input to bypass these wrong temperature values to prevent the computer shutting down this engine, too. As one engine was shut down, the other two were run for 9 minutes 41 seconds, about 1 minute longer than the normal 8 minutes 40-50 seconds burning time. The orbit attained was lower than desired but was high enough to fly a complete mission. Post-flight inspection of the temperature sensors proved that they had been in error.

The Maintenance Problems

Orbiter Atlantis had three flight-proven engines installed ready for its FRF on September 12, 1985: 2011 and 2019 from Columbia and 2017 from Discovery. With these engines Atlantis flew two missions (see Table 1).

After several months of overhaul, Columbia was brought back into service after STS-9 and engines 2015, 2018 and 2109 powered mission STS-61C into orbit. This flight was the last successful mission before the Challenger accident.

The performance of the SSMEs was satisfactory but NASA was not happy with so much inspection, repair, overhaul and replacement work that had to be carried out after nearly every mission. The aim was to use the engines on up to 55 missions without having to do major overhauls in between. Today the engines are certified for only 10-15 missions. After the Challenger accident 20 modifications were made, mainly improvements of the turbine blades, the temperature sensors and the cooling system.

Preparations For STS-26

Which engines will be used for the STS-26 mission on orbiter Discovery? Until October 1987, engines 2019,2022 and 2027 were planned. To that date engine 2027 had successfully passed all acceptance tests, then a leak in a fuel pipe was discovered. NASA stated that contamination in the metal from which the pipe was made had caused that leak. This meant that a production error was responsible for a kind of leak which had arisen for the first time in SSME history. To understand the nature of the error, more firings with the suspect engine were conducted. The results were positive as the leakage rate remained the same during all firings. A replacement for engine 2027 was found in engine 2028 which went through the acceptance tests without problems as did engines 2019 and 2022. During January 1988 all three engines were installed in Discovery. At the end of January technicians detected a welding problem in a test engine. It was caused by a wrongly aligned welding machine. As the turbopumps of engines 2019, 2022 and 2028 also came from the same production series as that of the test engine, NASA decided to replace all pumps. There was no need to remove the already installed engines from Discovery.

In April 1988 another liquid oxygen pump problem arose in two test engines. Some of the ten screws, that hold a retainer ring which secures the honeycomb seal at the turbine blade tips turned loose or tighten as a result of the engine's normal vibration when running. If the ring is secured too tightly or too loosely it can break. This caused NASA to remove all liquid oxygen pumps from the installed engines to inspect the screws of the suspect retainer rings. In mid-April NASA was sure that all screws remained in their original place and that the pumps could be reinstalled into the SSMEs.

On July 4th the whole Space Shuttle stack was rolled out to Pad 39B to await the FRF of the SSMEs prior to the STS-26 mission.

The first attempt was made on August 4, when less than a second before Main Engine start (T-6.6 sec), a sensor indicated a new fuel bleed valve sensor in engine No.2 (2022) was closing too slowly. The valve was later discovered to have operated correctly, NASA believed the sensor was incorrectly calibrated. A decision was made to replace the new bleed valve by an older one that had already flown on six missions.

This work was accomplished ahead of schedule, NASA therefore set the FRF for August 11.

Table 1. Use of the SSME flight units.

DATE	Orbiter	Event	Engine No.1	Engine No.2	Engine No.3
20.02.81	Columbia	FRF OV-102	2007	2006	2005
12.04.81	Columbia	STS-1	2007	2006	2005
12.11.81	Columbia	STS-2	2007	2006	2005
22.03.82	Columbia	STS-3	2007	2006	2005
27.06.82	Columbia	STS-4	2007	2006	2005
11.11.82	Columbia	STS-5	2007	2006	2005
18.12.82	Challenger	FRF OV-099-1	2011	2015	2012
25.01.83	Challenger	FRF OV-099-2	2011	2015	2012
	Challenger	leak in 2011	2016	2015	2012
	Challenger	leak in 2016	2017	2015	2012
04.04.83	Challenger	STS-6	2017	2015	2012
18.06.83	Challenger	STS-7	2017	2015	2012
30.08.83	Challenger	STS-8	2017	2015	2012
28.11.83	Columbia	STS-9	2011	2018	2019
	Challenger	replace 2017 by 2109	2109	2015	2012
03.02.84	Challenger	STS-41B/10	2109	2015	2012
	Challenger	replace 2015 by 2020	2109	2020	2012
06.04.84	Challenger	STS-41C/11	2109	2020	2012
02 06.84	Discovery	FRF-OV-103	2021	2018	2017
	Discovery	heatshield delamination	2109	2018	2017
26 06.84	Discovery	STS-41D/12 T-4 s abort	2019	2018	2017
30.08.84	Discovery	STS-41D/12	2109	2018	2021
	Discovery	replace 2021 by 2012	2109	2018	2012
	Challenger	two new engines	2023	2020	2021
05.10.84	Challenger	STS-41G/13	2023	2020	2021
08.11.84	Discovery	STS-51A/14	2109	2018	2012
24 01.85	Discovery	STS-51C/15	2109	2018	2012
12.04.85	Discovery	STS-51D/16	2109	2018	2012
29.04.85	Challenger	STS-51B/17	2023	2020	2021
17.06.85	Discovery	STS-51G/18	2109	2018	2012
12.07.85	Challenger	STS-51F/19 T-3 s abort	2023	2020	2021
29.07.85	Challenger	STS-51F/19	2023	2020	2021
27.08.85	Discovery	STS-51I/20	2109	2018	2012
12.09.85	Atlantis	FRF-OV-104	2011	2019	2017
03 10.85	Atlantis	STS-51J/21	2011	2019	2017
30.10.85	Challenger	STS-61A/22	2023	2020	2021
26.11.85	Atlantis	STS-61B/23	2011	2019	2017
12.01.86	Columbia	STS-61C/24	2015	2018	2109
28.01 86	Challenger	STS-51L/25	2023	2020	2021
04 08.88	Discovery	FRF-OV-103-abort	2019	2022	2028
	Discovery	replace valve in 2022	2019	2022	2028
11.98.88	Discovery	FRF-OV-103	2019	2022	2028
Sept /Oct.88	Discovery	STS-26	2019	2022	2028

INTERNATIONAL SPACE REPORT

A monthly review of space news and events

Energia Details Revealed

The Chief Designer of the Soviet Energia heavy lift launch vehicle, G. Gubanov, has revealed detailed information about the booster in a Pravda article.

Gubanov describes Energia as a multi-purpose rocket system capable of lifting a 100 tonne payload or a shuttle which, he says, 'is actively being prepared for its first launching.'

According to Gubanov, Energia has the following payload capacities:

Low Earth Orbit:	100 tonnes
Geostationary Orbit:	30 tonnes
Lunar Trajectory:	32 tonnes
Mars or Venus Trajectory:	28 tonnes

The Energia launcher comprises a central stage and four strap-on boosters, with the payload attached to one side. Gubanov says the strap-on boosters, which he describes as the first-stage, are fitted with a four-chamber liquid propellant rocket motor burning liquid oxygen and hydrocarbon fuel. These motors produce 740t of thrust at sea level and 806t in a vacuum.

The second stage central core burns liquid oxygen and liquid hydrogen and has four single-chamber liquid propellant rocket motors, each having a thrust of 148t at sea level and 200t in a vacuum.

Gubanov said the strap-on and core stage motors are ignited almost simultaneously just before lift-off. The total lift off thrust is 3,600t.

Gubanov implies that the strap-on boosters are not yet reuseable. Once the boosters' fuel is depleted the boosters separate in pairs, then split up and land in the designated area. He says the boosters *can* be fitted with re-entry and landing equipment housed in special compartments and be reused following, diagnostic, preventive-maintenance, repair and restoration work.

The core stage separates and splashes down in the Pacific Ocean, which prevents near-Earth space becoming littered with large discarded booster fragments. The boost to orbital velocity is supplied by motors on the space shuttle orbiter or payload.

The RD-170 rocket motors which are employed in the Energia first stage are standard for new generation launcher first stages. Gubanov adds that the engines were built in the most economical and compact layout – in which the gas used in the turbine is ignited in the main combustion chamber. He claims that the engines have produced a record performance in their class in terms of thrust and specific impulse, their high power turbopump units produce more than 250,000 hp.

Gubanov states that the second-stage central core has reuseable engines and says, this 'was a considerable achievement for Soviet rocket construction. The designers managed to ensure high performance characteristics with minimal gas-dynamic losses, regenerative cooling and durability of the materials used in a liquid hydrogen environment.'

The new booster, which must be man-rated if it is to launch the Soviet shuttle, has many safety systems and can shut down an engine the moment a malfunction is detected. 'The booster is fitted with efficient fire or explosion warning systems.' Gubanov added.

Gubanov reveals some of the abort modes for the Soviet shuttle, which appear similar to the US shuttle procedures. If the Energia booster fails towards the end of the ascent the shuttle can make one low orbit and land at an airfield, the equilivent of the US Abort Once Around. If a malfunction occurs early in the launch the shuttle can carry out a manoeuvre to land on a strip located near the launch complex, similar to a US Return to Launch Site Abort.

The Energia booster went through a test firing of its first and second stages on the launch pad, similar to the US Shuttle Flight Readiness Firings. The booster's engines were fired for almost their full burn duration.

The huge Energia launch pad has a plume deflecter 40 metres below ground level and lightning conductors which tower 225 metres above. The cryogenic fuelling system is fully automated and uses modern computer technology.

Energia core stage components are eight metres in diameter and weigh up to 40 tonnes. A heavy aircraft has been specially modified to transport them from their construction sites to the launch complex.

In conclusion, Gubanov says that the most immediate problem with the booster is concerned with reusability. This will need to be solved if the cost of placing a unit mass of payload into orbit is to be reduced.

Cosmonaut Dies

We are sorry to record the death of Soviet cosmonaut Anatoliy Levchenko on August 6. The cosmonaut died of a brain tumour despite an emergency operation to save him. The Soviet press agency TASS denied his death was is any way connected with his space flight.

Levchenko, a top test pilot recruited for the Soviet space shuttle programme, was expected to fly the spacecraft's first manned mission with fellow cosmonaut Igor Volk

Levchenko spent a week in orbit during December 1987 when he served as the Flight Engineer for Soyuz TM-4. Directly after his return to Earth he flew a shuttle simulator aircraft to evaluate the problems of flying while still adapting to gravity

Although his death is a blow to the Soviet space programme it is unlikely to affect the first manned launch of the Soviet shuttle which is not expected for some time.

Cosmonaut Anatoliy Levchenko seen here shortly after the completion of Soyuz TM-4. *Novosti*

INTERNATIONAL SPACE REPORT

Britain Joins Sun Missions

Britain is to collaborate in two space projects to investigate the Sun. It is the UK's largest ever participation in an international space mission.

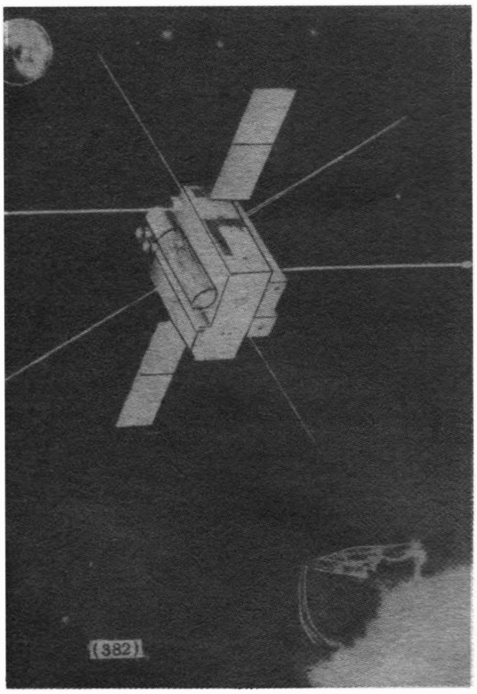
The British National Space Centre and the Science and Engineering Research Council (SERC) are to fund the £76 million project. The two missions will investigate the Sun's interior and how this interacts with the Earth's magnetic field and environment.

Contracts to the value of around £64m will be placed in the UK over the next eight years, benefiting instrument makers, spacecraft manufacturers and many small companies. The technology employed will need to be at the leading edge of scientific know-how and should result in many spin-offs of wider value to the UK.

The two Missions – Soho and Cluster – are part of the European Space Agency's 20-year science programme "Horizon 2000". The first cornerstone mission to be implemented within this programme is the Solar Terrestrial Science Programme (STSP) comprising Soho and Cluster. They will be undertaken by ESA in association with NASA at a total cost of £800m. There is also the possibility that the Soviet Union could join the Cluster mission.

The object of the two missions is to investigate the critical stages in the chain of events associated with the ejection of high speed ionised material from the solar surface.

The Soho Sun Probe. *Matra*



Soho (Solar and Heliospheric Observatory) will measure changes in the structure of the Sun. It is known that the Sun's core constantly vibrates and the oscillations travel like sound waves. By analysing surface fluctuations, details of the Sun's inner core will be recorded.

Four identical spacecraft forming Cluster will investigate the evolution and properties of plasma in the Earth's magnetosphere and the reactions to the varying solar conditions.

China Launches West German Experiments

On August 5, at 0730 GMT, China successfully launched a recoverable satellite using the Long March 2C vehicle. The launch took place from the Jiuquan Satellite Launch Centre situated in the Gobi Desert in Gansu Province.

The recoverable satellite contained a 'piggyback' payload sponsored by the West German company MBB/ERNO, the European consortium Intospace, and the West German Aerospace Research Agency DFVLR. The capsule also contained experiments for the Chinese Academy of Sciences and other research institutes in China.

West Germany hoped to find new ways of producing Interferon by producing large and pure crystals from proteins or other macro-molecules. Peter Vits director of MBB/ERNO said the cost of launching the company's payload was about DM 700,000 (US$374,500).

The satellite's orbital elements were released as an example of the Long March's reliability, they were:

	Actual	Intended
Inclination	: 62.8 degrees	63 degrees (+or– 3)
Apogee	: 319.5 Km	325.43 Km (+or – 5)
Perigee	: 205 Km	210 Km (+ or – 5)
Period	: 5,361.6 degrees	5383.5 seconds (+ or – 8)

After eight days in orbit the satellite was successfully recovered during the afternoon of August 13 from a pre-determined area in the Sichuan Province.

The payload was returned to its owner on August 14 representatives of the West German companies involved expressed their satisfaction over the success of Sino-Federal German cooperation in space technology.

Chen Shouchun, Chief Engineer from the China Great Wall Industrial Corporation, said the success of the piggyback service once again shows the reliability of Chinese carrier rockets and satellites.

This was the second time China has provided a piggyback service for foreign clients. The first was for the Matra company of France in August last year.

Spacehab and NASA Sign Agreement

NASA and Spacehab Inc. have signed an agreement that provides for six flights of the privately financed shuttle-based module beginning in 1991 *writes Roelof Schuiling.*

Under the terms of the agreement, Spacehab will pay $28.2 million for each flight within 30 days of completion of the mission. Spacehab does not use the entire shuttle payload bay and the mission charge is based on the module's share of a mixed payload complement. At the actual time of the flight, the charge will be escalated to account for any economic inflation.

McDonnell Douglas has been selected as the prime contractor for the final design and construction of the modules. Subcontractors are: Aeritalia and United Technologies Corp.

Space Station Go-Ahead

NASA's budget for 1989 has been set at $10.7 billion (an increase of $1.7 billion over 1988). NASA had requested $11.5 billion but was expecting to receive much less. Fears that the Freedom space station would be crippled by budget cuts have now been laid to rest, the project is to receive $902 million. NASA was pleasantly surprised by the budget outcome, for the US Senate had initially approved just $200 million for Freedom (*Spaceflight*, September 1988, p.345).

Vigorous 'salesmanship' by NASA's supporters in Congress won the support of many of the space station's former opponents, with the result NASA's budget won approval at the conference stage by seven votes to six, from the House of Representatives by 373 to 30 and in the Senate by 88 to eight.

The Freedom project will receive $385 million in October 1 (the start of the US fiscal year) and $515 million if the new President approves. Republican presidential candidate, George Bush, is well known as a supporter of the space station and his Democrat rival, Michael Dukakis, has also recently voiced his approval for the project.

So whatever the election result the space station's future now looks politically safe.

Palapa-B2 to be Relaunched

The Palapa-B2, one of two Hughes satellites that made history in 1984 by being the first to be retrieved from space and brought back to Earth, is being prepared for a return trip into space.

Space and Communications Group is under a $14-million contract from Sattel Technologies to refurbish the Palapa satellite to help link together through telecommunications Indonesia's 13,000 islands, the purpose for which it was originally intended.

The refurbishment is expected to take about 16 months, which will be in time to meet a March 1990 launch.

Sattel bought Palapa-B2 from insurance underwriters in 1986 and renamed it the Palapa-B2R.

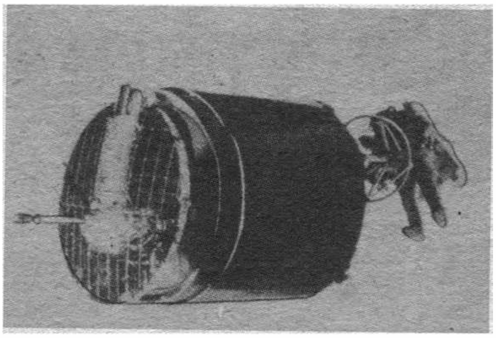
When launched, Palapa-B2R will be the first satellite returned to space.

It and a similar satellite, Westar VI built for Western Union, were released from the Space Shuttle in early 1984, but had to be recovered after onboard rocket motors shut down prematurely, leaving the satellites stranded in improper orbits.

The satellites became the property of space insurance underwriters as a result of the malfunction.

Sattel Technologies purchased Palapa-B2R from a consortium of underwriters represented primarily by Merrett Syndicates, Ltd., of London, and International Technology Underwriters, Inc., of Washington, D.C.

PERUMTEL, Indonesia's telecommunications agency and the original owner of Palapa-B2, has agreeed to buy the refurbished satellite and associated launch and insurance services from Sattel.



Astronaut Joe Allen recovers the Palapa B-2 satellite from a useless orbit during shuttle mission STS 51-A. *NASA*

Telecommunications services to Indonesia's archipelago are currently provided by two other Hughes satellites, Palapas B1 and B2P.

National Aeronautics and Space Administration BUDGET SUMMARY (Millions of Dollars)

	FY 1988	FY 1989
RESEARCH AND DEVELOPMENT		
Space Station	392.3	967 4
Space Transportation Capability Development		
Upper Stages	154.9	146 2
Spacelab	66.5	80.4
Engineering & Technical Base	133.9	158.9
Payload Operations & Support Equipment	84.6	67 3
Advanced Program	46 4	45.0
Tethered Satellite System	12.1	23.8
Orbital Manoeuvring Vehicle	46 3	96.5
Advanced Launch Systems	65.1	13.0
Space Science and Applications		
Physics and Astronomy		
Hubble Space Telescope Development	93.1	102.2
Gamma Ray Observatory Development	53 4	41.9
Advanced X-ray Astrophysics Facility	0.0	27.0
Global Geospace Science	20.0	101 4
Shuttle/Spacelab Payload Mission Management & Integration	54.2	61.5
Payload and Instrument Development	43.7	77.1
Space Station Integrated Planning & Attached Payloads	18.9	8 0
Explorer Development	67.9	82.1
Mission Operations & Data Analysis	132.0	156.2
Research and Analysis	82.9	89.1
Suborbital Program	44.7	45.1
Life Sciences		
Life Sciences Flight Experiments	30.9	54 5
Research and Analysis	38.6	47.2
Planetary Exploration		
Galileo Development	51.9	61.3
Ulysses	7.8	10.3
Magellan	73.0	33.9
Mars Observer	53 9	102.2
Mission Operations & Data Analysis	74 7	112.7
Research and Analysis	67 9	83.6
Space Applications		
Solid Earth Observations		
Payload & Instrument Development	20.8	25.3
Applied Research, Data Analysis and Related Activities	53.5	56.8
Environmental Observations		
Payload & Instrument Development	4.1	19.7
Applied Research, Data Analysis and Related Activities	100.2	108.1
Airborne Science and Applications	21.9	23.0
Scatterometer	22.7	15.8
Upper Atmosphere Research Satellite	89.6	103.9
Ocean Topography Experiment	75.0	97.8
Materials Processing	62.7	73.4
Space Communication	94.9	16.2
Information Systems	20.9	22.3
Commercial Program		
Technology Utilization	17.7	19.1
Commerical Use of Space	56.0	38.8
Aeronautical Research and Technology		
Research and Technology Base	251.6	314.2
Systems Technology Program	83.2	100.0
Space Research and Technology		
Research and Technology Base	108.4	134.1
CST 1	115.2	156.8
Transatmospheric Research and Technology	52.5	84.4
Safety, Reliability and Quality Assurance	14.1	22.4
Tracking and Data Advanced Systems	17.9	18.8
SPACE FLIGHT, CONTROL AND DATA COMMUNICATION		
Shuttle Production and Capability Development		
Orbiter	328.6	320.0
Propulsion	594.9	711.8
Launch & Mission Support	164.8	3443.7
Changes & Systems Upgrade	0.0	25.0
Space Shuttle Operations		
Flight Operations	583.6	660.1
Flight Hardware	776.6	1035.2
Launch & Landing Operations	449.8	195.5
Expendable Launch Vehicles	28.0	195.5
Space and Ground Networks, Communications and Data Systems		
Space Network	435.7	538.9
Ground Network	232.2	248.1
Communications and Data Systems	216.5	248.3
TOTALS		
Research and Development	3294.5	4446.7
Space Flight, Control, and Data Communication	3810.7	4841.2
Construction of Facilities	178.3	285.1
Research and Program Management	1743.0	1915.0
TOTAL BUDGET	9026.5	11488.0

SATELLITE DIGEST — 215

Robert D. Christy

Continued from the August 1988 issue

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

SOOS 3A & 3B, 1988-33A & B, 19070 & 19071
Launched: 0204, 26 April 1988 from Vandenberg AFB by Scout.
Mission: Navigation satellites placed in orbital storage until required for use.
Orbit: 1019 x 1307 km, 108.68 min, 90.36 deg.

COSMOS 1940, 1988-34A, 19073
Launched: 0315, 26 April 1988 from Tyuratam by D-1-e.
Spacecraft data: Possibly a stepped cylinder with a sensor array at one end. Electrical power may be provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is probably about 5 m, and the maximum diameter about 2 m. The mass is around 2000 kg.
Mission: Oceanographic and atmospheric studies satellite.
Orbit: Geosynchronous above 24 degrees west longitude.

COSMOS 1941, 1988-35A, 19079
Launched: 0910, 27 April 1988 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 224 x 257 km, 89.35 in, 70.34 deg.

KRAN 18, 1988-36A, 19090
Launched: 0247, 6 May 1988 from Tyuratam by D-1-e.
Spacecraft data: Stepped cylinder with an aerial array in the form of a 6 m x 2 m rectangular panel at one end. Electrical power is provided by a pair of rotatable, boom mounted solar panels at the opposite end of the body, and positioned at right angles to it. Station keeping is by the use of gas jets, and three-axis estabilisation is achieved by momentum wheels. The length is about 5 m, the maximum diameter about 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing television and radio services to community aerials in remote areas of the USSR.
Orbit: Geosynchronous above 99 deg east.

COSMOS 1942, 1988-37A, 19115
Launched: 1440, 12 May 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 166 x 361 km, 89.80 min, 67.14 deg, manoeuvrable.

PROGRESS 36, 1988-38A, 19117
Launched: 0030*, 13 May 1988 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carrying a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried equipment and consumable supplies to the resident crew of Mir. It docked with Kvant's aft-facing hatch at 0213 on 15 May. At 1012 on 5 June, it undocked and was commanded to re-enter at 2028 the same day.
Orbit: Initially 185 x 246 km, 88.75 min, 51.66 deg, then by way of a 223 x 334 km transfer orbit to a docking with Mir in an orbit of 331 x 357 km, 91.36 min, 51.62 deg.

COSMOS 1943, 1988-39A, 19119
Launched: 0927, 15 May 1988 from Tyuratam, by J-1.
Spacecraft data: not available, but probably several tonnes mass.
Mission: Electronic intelligence gathering.
Orbit: 849 x 851 km, 101.97 min, 71.02 deg.

INTELSAT 5A (F-13), 1988-40A, 19121
Launched: 1158*, 17 May 1988 from Kourou by Ariane 3 (V-23).
Spacecraft data: Box shaped body, 1.66 x 2.10 x 1.77 m with attached 4 m aerial mast and a 15.9 m span solar array. The mass before apogee boost motor firing was 2013 kg, reducing to 1096 kg on total depletion of fuel. The vehicle is three-axis stabilised by momentum wheels, and station keeping is by the use of gas thrusters.
Mission: Communications satellite providing the equivalent of 15000 telephone channels at C-band and L-band.
Orbit: geosynchronous above 53 deg west.

COSMOS 1944, 1988-41A, 19123
Launched: 1030, 19 May 1988 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 212 x 261 km, 89.24 min, 64.79 deg, manoeuvrable.

Record Engine Test

On August 3 the longest test firing of a space shuttle main engine took place at the John C. Stennis Space Center in Mississippi.

The static test firing was carried out on the Center's new B-1 test stand. Engine 2206 ran for 2,017 seconds (almost 34 minutes), during that time the engine consumed 510,000 gallons of liquid hydrogen and 210,000 gallons of liquid oxygen and over 10 million gallons of water were used to cool the test stand's diffuser and flame bucket.

The previous longest test firing was 1,078 seconds also made by engine 2206 on July 26 and July 30 of this year, several more long-duration tests are planned for this engine.

Roelof Schuiling

Discovery on Launch-Pad

Phillip Chien **watches the Flight Readiness Firing (FRF) of Discovery on Pad 39B and sends this special report for** *Spaceflight* **on the abortive attempte on August 4th, and the successful firing on August 10th.**

August 4, 1988: Everything's go for FRF at 7am. The final nine minute countdown starts at 7:21. Applause greets the T-31 Go for Auto-sequence Start command (the time when the ground launch computer takes over control of the launch sequence). By the final 10 seconds everybody's confident that we are actually going to get those engines fired today.

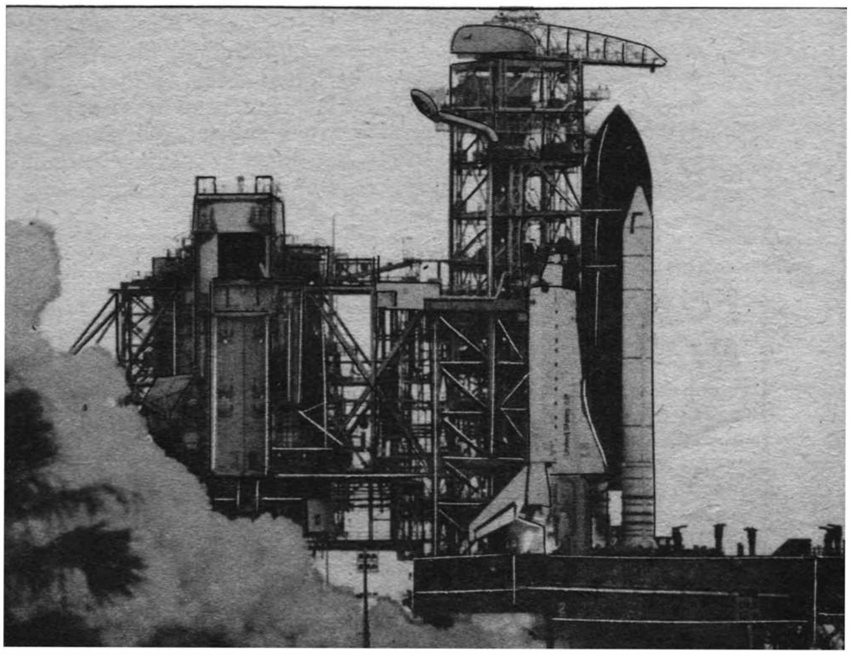
At T minus six seconds, the controller on engine No. 2 indicated that a valve was not closed enough, and the ground launch computer stopped the test just before the command for engine ignition. The launch crew immediately went through the saving procedure and the propellants were drained from the External Tank.

This was the closest ever to a main engine ignition without actually igniting the engines. The next closest case was in December 1985 when Columbia came within 14 seconds of flight when the ground launch computer stopped the countdown due to a problem with the SRB's hydraulic unit. That flight eventually launched in January 1986 after a record seven delays – the last successful launch before the Challenger accident.

Discovery's problem was due to a bleed valve sensor. Before launch a small amount of ultra-cold liquid hydrogen is fed through the lines to prevent a thermal shock when the massive amount of fuel is fed a couple of seconds later. The bleed valve is used to shut off that flow and protect fuel lines not designed to take extremely high pressure fuel. If the valve has not closed to at least 20 per cent the engine controller indicates that the engine is not ready and prevents the launch.

As it turned out the valve was closing properly and the sensor gave a false reading. Engineers decided to replace the entire valve/sensor assembly before attempting another FRF, adding another week of delays to Discovery's launch. The replacement bleed valve, sensor, and accompanying ducting came off engine 2107. The changeout operations and inspections of the shuttle took sixteen hours less than expected, and NASA decided to try for another FRF attempt on August 10th, a day earlier than original estimates.

August 10, 1988: Everybody's back in place and the mood is optimistic. The main nagging concern today is the weather: there are light showers and thunder clouds over the Cape, and a large mass of clouds in the Atlantic – certainly not launch weather today. The primary weather restrictions for the FRF are good visibility for the cameras, no rain which may harm the tiles, and no lightning within the five miles. The weather is marginal, but the count picks up at T-9 minutes. At T-31 seconds the shuttle's launch computers take over and the breath-holding begins again. At T-7 seconds the 'go' is given for the main engine start. This time everything's perfect, and right on schedule the three engines light up in sequence. The shock and noise is nothing like a normal launch; the SRBs provide most of that. But the cloud of water vapour from the engines is still impressive. The engines burn at the 100 per cent level for an average of 20 seconds, the first engine slightly longer, and the last engine slightly less. At T+15 seconds the launch computer is given an overload condition and as programmed it shuts down the three engines in order. Massive amounts of water are sprayed on the shuttle from ground hoses to cool it down and quench any fires which may have started on the launch pad. The launch crew immediately go through the process to save the orbiter and unload the unused fuel remaining in the External Tank.



August 10, 1988: The Flight Readiness Firing is conducted on Pad 39B. *NASA*

Fuel Leak Fixed

As reported in the September issue of *Spaceflight* **(p.350) a small fuel leak was detected in the left OMS (Orbiter Manoeuvering System) pod used to control the shuttle while it is in space.** *Phillip Chien* **reports on how this was finally fixed.**

Managers decided to make an access hole in the back of Discovery's cargo bay and put a clamshell-like clamp over the leak filled with a caulk to completely contain the leak. The fix involved cutting two access holes into the back of the cargo bay and manually placing the clamshell assembly in place on top of the leak.

Since the shuttle is in its upright position on the launch pad the technicians had to cut into the 'floor' of their work area. Two access holes were cut into the bulkhead using an electrical router with a vacuum to remove filings. Another two holes were cut into the OMS pod to gain access to the area of the leak. The Rockwell technicians then reached in with their hands and placed the clamp around the leak and screwed it in tight. An caulk-like mixture of graphite, fiberglass, and silicone was squeezed into the clamshell under pressure where it hardened sealing the leak. Finally the valve where the caulk was injected was capped.

Discovery—A

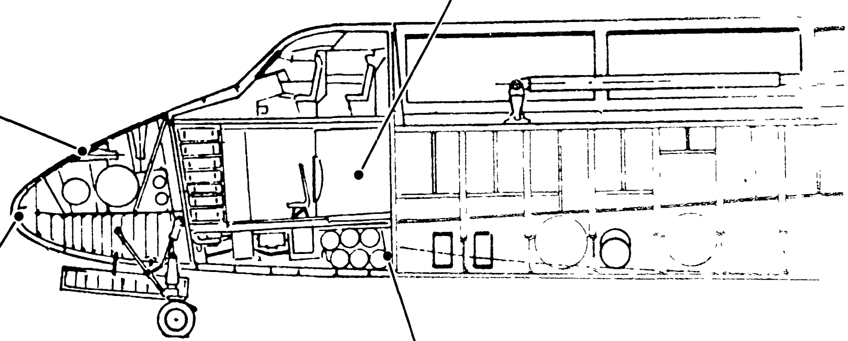
Although the redesign of the Solid Rocket Booster (SRB) field joint has received most attention since the Challenger disaster it is not the only area where modifications have taken place. Following the loss of Challenger a review of all aspects of the shuttle vehicle began. Approximately 220 changes have been made to the orbiter, and about 30 to the Space Shuttle Main Engines. NASA considers Discovery to be 'a new orbiter'. Here we take a look at just some of the modifications.

Forward RCS Thrusters

The orbiter's Reaction Control System (RCS) engines which provide on-orbit attitude control have been modified to automatically shutdown if they experience thrust instability and/or chamber wall burn-through. Previously a shuttle commander could continue firing a thruster that had unknowingly burnt through its casing and the result would have been catastrophic.

Crew Escape System

- Explosive bolts to jettison side hatch
- Telescopic pole installed
- Emergency egress slide



Thermal Protection System

Two significant design changes to the orbiter's Thermal Protection System (TPS) have been made. The TPS in the wing elevon cove region has been damaged on several previous flights and a new design has been employed for future shuttle flights.

A new carbon panel has replaced the TPS tiles on the forward end of the orbiter between the nose cap and the nose wheel door. Because of its position it is known as the carbon-carbon chin panel.

Fuel Cells

An improved design of the fuel cell power unit subsystem has been implemented to provide an alternative path for removing water generated by the cells. This new path provides greater physical separation from the other two paths and reduces the possibility of the pipes becoming frozen and blocked. Blockage of these paths would result in loss of the three fuel cells and all orbiter power within a very short time.

New Orbiter

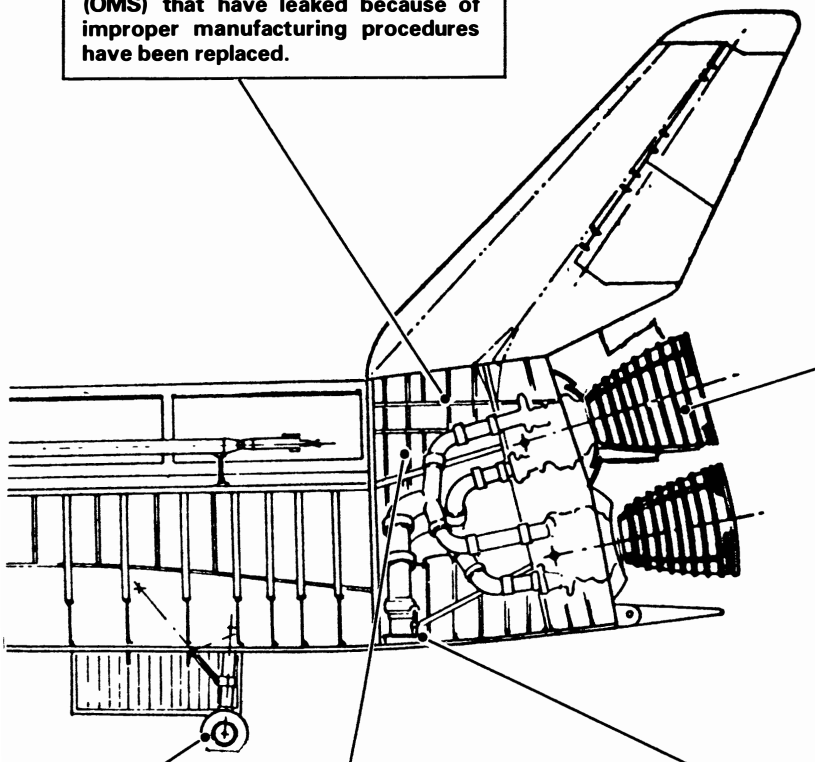
Orbital Manoeuvring System

Alternating current valve bellows in the Orbital Manoeuvring System (OMS) that have leaked because of improper manufacturing procedures have been replaced.

Main Engines

Prior to the Challenger disaster there were concerns about the Space Shuttle Main Engines (SSME). Since then changes have been made to increase the operating life, safety, reliability and quality of the engine. (The history of the SSME can be found on p.378).

- Modifications were made to the SSME high-pressure turbopump blades to significantly reduce the susceptibility to cracking in structurally critical areas.
- Improvements in the structural capabilities of components such as the main fuel valve housing and the main combustion chamber outlet neck will result in a significant increase in useful life.
- Changes to the high-pressure fuel turbopump coolant circuit will reduce the overall operating pressures and the redline (engine shutdown) values.
- The current hydraulic actuators have been replaced with actuators that have improved manufacturing cleanliness requirements and design modifications to reduce the susceptability to electrical shorts These changes will reduce the possibility of launch pad aborts.



Main Landing Gears

- Axles stiffened
- Brakes modified

Auxiliary Power Units

An electrical interlock has been added to the Auxiliary Power Unit (APU) tank shut-off valves to preclude electrical failures that could overheat the valves and cause decomposition of the hydrazine fuel.

17-Inch Disconnect Valve

The main propulsion system 17-inch disconnect valve, is located between the External Tank (ET) and the orbiter. It closes after main engine cut-off to prevent propellant spilling during the ET separation. Tests indicated the valve 'wobbled' during flight, and there was the possibility it could slam shut, cutting off fuel to all three main engines. As a result a latch has been added to the valve which holds it in position until it is commanded to close.

EGRESS!

By Kelly Humphries

A launch-pad emergency could lead to unsuspected hazards for a waiting shuttle crew and any supporting close-out crew still on the Fixed Service Structure. Following a detailed safety review, procedures and equipment for emergency evacuation have been introduced and were put to the test earlier this year.

A Space Shuttle crew prepares for launch from Pad 39-B. Five crew members are in either the crew compartment or the "white room" waiting to enter the Orbiter; two are still on the Fixed Service Structure.

Smoke is spotted on the launch tower. An alarm sounds. There is fire in a Hydraulic Control Unit. The pad will have to be evacuated.

That was the situation on May 4 this year, when Astronauts Kathy Thornton, Frank Culbertson, Sam Gemar, Ken Cameron, Jay Apt, Pierre Thuot and David Low began a simulated emergency egress at Kennedy Space Center (KSC). They comprised the Flight Emergency Egress Test (FEET) crew.

It was the first of three simulations that week designed to familiarise the astronauts, the launch team, the fire and rescue team, the ice inspection team and the close-out crew with evacuation routes, emergency equipment and procedures during both prelaunch and landing at KSC.

"The objective was to verify that all the changes put in place since 51-L are right, and work as expected, and are ready for STS-26," said Thornton, who headed up the Johnson Space Center (JSC) Astronaut Office contingent at all three simulations (sims). "I think we achieved that with flying colours."

In the May 4 sim, the emergency scenario was announced as five of the crew members were in the white room, the environmental chamber that connects the access arm to the crew compartment hatch. Four of the simulated crew members were dressed in the new partial pressure suits that will be worn during launch and landing.

When the order to evacuate was given, the two crew members still on the Fixed Service Structure (FSS) returned to the elevator, put on their air supplies and headed for the slide-wire baskets. The rest ran back across the Orbiter Access Arm (OAA) through a deluge of water.

During their evacuation, test officials handed Commander Frank Culbertson a card stating that he had suffered a head injury. Mission Specialist Sam Gemar received a broken leg card. The close-out crew and fellow crew members helped the injured don their air supplies and get into slide-wire baskets.

The astronauts and close-out crew members then got out of the baskets and descended to ground level on the launch tower elevator. The baskets were loaded with sand bags and released, one by one, to slide safely to the ground. The crews then got back into the baskets to simulate unloading in the same order they would have arrived had they actually slid down in the baskets.

After getting out of the baskets, crew members who were able ran to the nearby underground bunker, reported who was there and who was not. Rescue workers helped the injured crew members to the bunker.

Rescue crews wheel astronaut Sam Gemar, feigning a broken leg, to the emergency bunker. *NASA*

The crew was helped into the M113 armoured personnel carrier, which carried them to a triage site where helicopters were waiting to fly the injured to Jess Parrish Memorial Hospital five to 10 minutes away.

"I thought it all went very smoothly from the start to the end," Thornton said. "The slide wire baskets worked well. The bunker was a tremendous improvement over what we used to have. The handover from fire rescue to triage went smoother than any other test we have done."

Several modifications have been made to the emergency egress system to increase safety margins.

Fire-protection plating has been added to the access arm and the 195-foot level of the FSS. Additional fire detectors have been installed on the FSS, and the water spray system has been upgraded to better cover the egress paths. Lighting has been improved in case of a night emergency.

Two slide-wire baskets have been added to the FSS, making a total of seven baskets. Baskets have been rated to hold three instead of four people. They have been modified to incorporate a side exit, add a flame-protective covering over the existing webbed material, and install an anti-roll brake to stop the basket more quickly. A rope arresting net at the end of the slide-wire provides a backup should the braking system fail.

A new underground, steel-reinforced concrete bunker with a foot-thick roof and 15-inch-thick walls has been built, and access to the bunker has been improved. The bunker contains emergency air, an emergency shower, a telephone and four fold-down bunks.

"We have got a few more things to review, but by and large we are finished and we can wrap it up now and get ready to go fly," Thornton said.

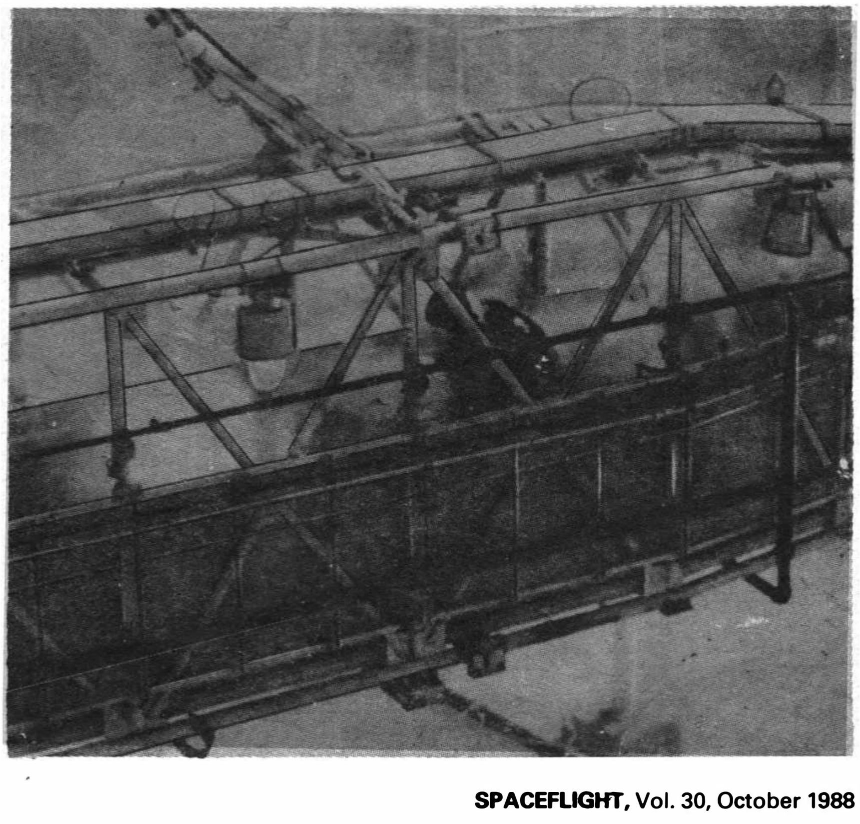
All three of the tests went smoothly, said Thornton, who has been working with the Emergency Escape and Rescue Group for about a year and a half.

"I think everybody on all of the teams is just interested in getting the job done," Thornton said.

The bottom line, of course, is how well the equipment and procedures work in a real emergency. How would she feel if she were really in that situation?

"I'd be confident that we would get out safely."

A flight crew member dashes through a water deluge on the Orbiter Access Arm. *NASA*



CREW ESCAPE

The Presidental Commission investigating the Challenger accident recommended that NASA should: "make all efforts to provide a crew escape system for use during controlled gliding flight." The Commission recognised these was no feasible escape system that could be used during the launch while the Solid Rocket Boosters were firing.

A study to determine the options for crew escape was initiated in April 1986. A final decision on the escape system was made early this year allowing time to install the equipment ready for STS-26.

The telescoping pole bail-out concept was chosen as the escape system for future shuttle flights after extensive tests over Edwards Air Force Base in California. Over 60 parachute jumps using the pole were made from a C-141 aircraft.

The system offers extraction for the full complement of eight crew members in about two minutes.

To install the system only minimal modifications are required. The pole weighs only 241 pounds, as a result the weight penalty is small, it occupies little space in the orbiter's middeck. Development of the pole cost only $2.3 million, compared with $70 million spent researching other escape systems.

A Navy parachutist tests the telescoping pole bailout method from a C-141 aircraft. *NASA*

The escape sequence begins with the opening of a valve to equalise internal cabin pressure with that outside. At an altitude of approximately 22,000 feet the side hatch is jettisoned by pyrotechnic devices and the 2.94m telescopic pole, angled 45 degrees down and 15 degrees aft, is deployed through the open hatch. At about 20,000 feet and a velocity of 200 miles per hour the escape can begin. One by one the crew attach a lanyard on their suits to the pole, and leap from the hatch in a tucked position. The rod releases them at a point where there is no danger of colliding with the orbiter. The astronaut's parachute opens about five seconds later.

Each crew member wears a partial pressure suit with a self-contained air supply and is equipped with a survival kit, including a radio beacon and a small raft.

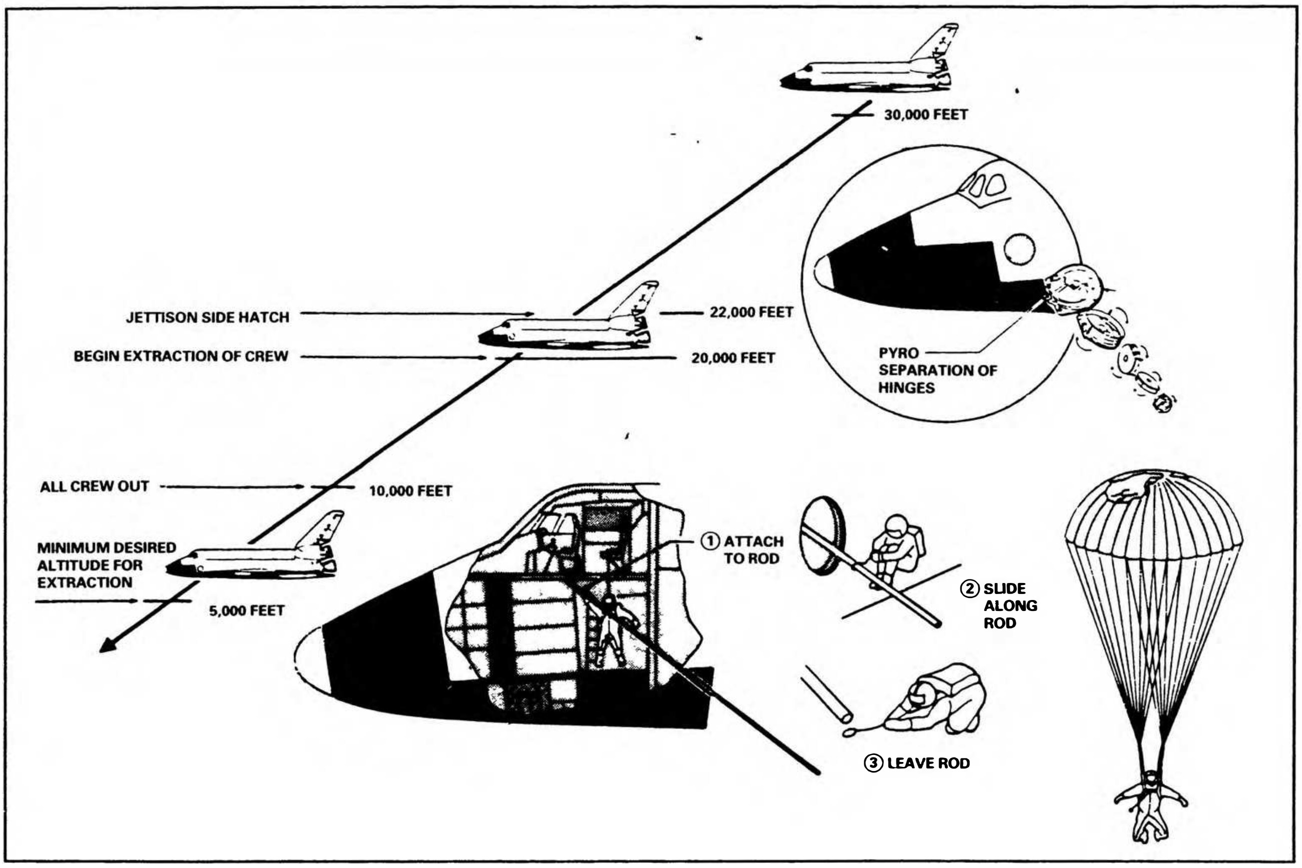
Other Escape Systems

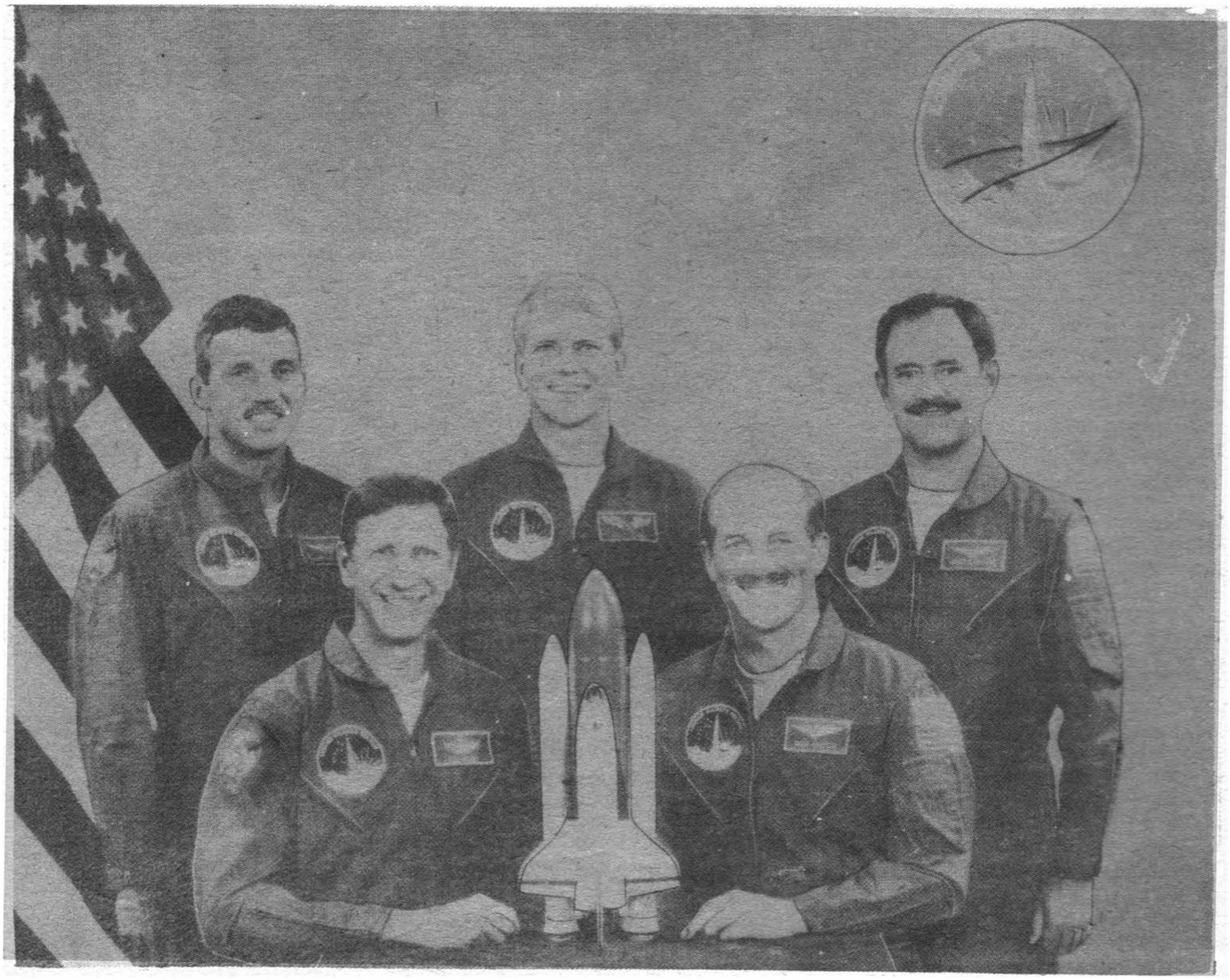
Four other types of escape systems were evaluated but found to be less suitable. The following was runner-up to the telescoping pole.

Tractor Rocket Bail-out

A concept in which astronauts escape through the side hatch using tractor rockets could safely extract up to eight astronauts.

Internal and external pressures are first equalised, the side hatch is then jettisoned. The crew members would then exit sequentially using tractor rockets. Required changes include addition of a cabin vent, modification of the side hatch structure to allow for hatch jettison, addition of pyrotechnic devices to jettison the hatch and installation of the tractor rocket system. This method of escape was one of the two final candidates, but turned down in favour of the telescoping pole concept.





STS-26 Crew. Astronauts Frederick H. (Rick) Hauck (right front), mission commander, and Richard O. Covey (left front), pilot, are flanked by NASA's STS-26 mission specialists (left to right) David C. Hilmers, George D. (Pinky) Nelson and John M. (Mike) Lounge.

NASA

MILESTONES TO RECOVERY

–1986–

28 January
The Space Shuttle Challenger exploded 73 seconds after launch. All seven crew members were lost.

3 February
President Reagan established the Presidential Commission on the Space Shuttle Challenger Accident. William Rogers becomes the Commission's Chairman.

March
Dr. James Fletcher replaced Dr. William Graham as NASA Administrator.

24 March
The NASA Marshall Space Flight Center was directed to form a solid rocket motor redesign team to evaluate possible improvements.

7 April
NASA initiated a Shuttle Crew Egress and Escape Review.

6 June
The Presidential Commission published its report, a faulty O-ring seal on the right hand solid rocket booster was responsible for the disaster.

July
On safety grounds NASA decided to terminate the Centaur upper stage that was due to launch interplanetary probes from the shuttle.

15 August
President Reagan gave NASA permission to build a replacement orbiter for Challenger.

8 October
Atlantis was moved to Pad 39B for a series of tests.

–1987–

5 January
Challenger's debris are 'buried' in two disused Minuteman missile silos at the Cape Canaveral Air Force Station.

9 January
NASA announces Discovery's crew for STS-26:

Commander:	Rick Hauck
Pilot:	Dick Covey
Mission Specialists:	George "Pinky" Nelson
	David Hilmers
	John Lounge

2 April
Discovery's crew hatch was removed for modifications to enable it to be jettisoned for crew escape.

27 May
The first full-scale Solid Rocket Booster test firing was conducted.

8 June
Orbiter Enterprise was used to evaluate the orbiter arrest net concept at Washington's Dallas International Airport.

3 August
Discovery was powered up in the Orbiter Processing Facillity.

30 August
The Demonstration Motor(DM)-8 test was carried out at Morton Thiokol's Wasatch plant.

10 October
During acceptance testing at the National Space Technology Laboratories a leak was discovered in main engine 2027 due to be used for STS-26.

20 October
The STS-26 crew and mission control team took part in a 54-hour simulation of the flight.

23 December
Problems with the main engines were resolved and the test programme was completed. The full-scale DM-9 Solid Rocket Booster test firing resulted in the failure of an outer boot ring delaying STS-26 considerably.

–1988–

29 February
NASA announced its intention to buy a second 747 Shuttle Carrier Aircraft.

2 March
The telescoping pole escape system was tested over Edwards Air Force Base.

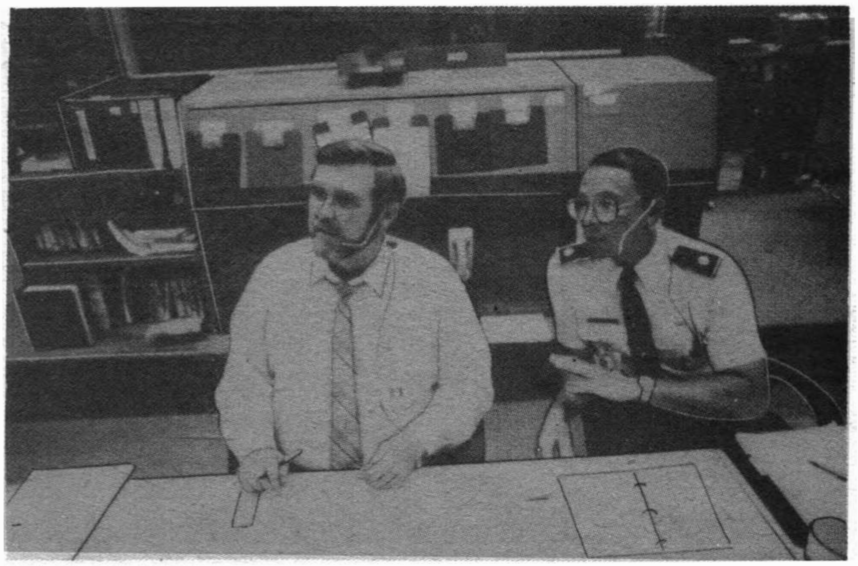
29 March
The marathon 36-hour simulation of mission STS-26 began. Involving both the flight crew and the Mission Control team, the simulation was conducted in the Shuttle Mission Simulator at the Johnson Space Centre.

20 April
Qualification Motor-6 full-scale test firing was successfully conducted.

4 May
An exercise on Pad 39B was conducted to evaluate shuttle escape procedures.

10 June
The External tank is attached to the Solid Rocket Boosters atop the mobile launch platform.

14 June
The Qualification Motor-7 test firing of a full scale Solid Rocket Booster was successfully conducted on Morton Thiokol's new test stand.



20 October 1987: Flight Directors Lee Driscoe (left) and Charles Shaw view a large monitor in the flight control room of JSC's mission control centre during STS-26 simulations.
NASA

21 June
Discovery was rolled out from the Orbiter Processing Facility to the Vehide Assembly Building.

25 June
Operations to mate the Orbiter with the external tank and Solid Rocket were completed.

4 July
Discovery was rolled out to pad 39B during the early hours of the morning, the shuttle was hard down on the pad at 8:42am.

28 July
Wet Countdown Demonstration Test Countdown restarted.

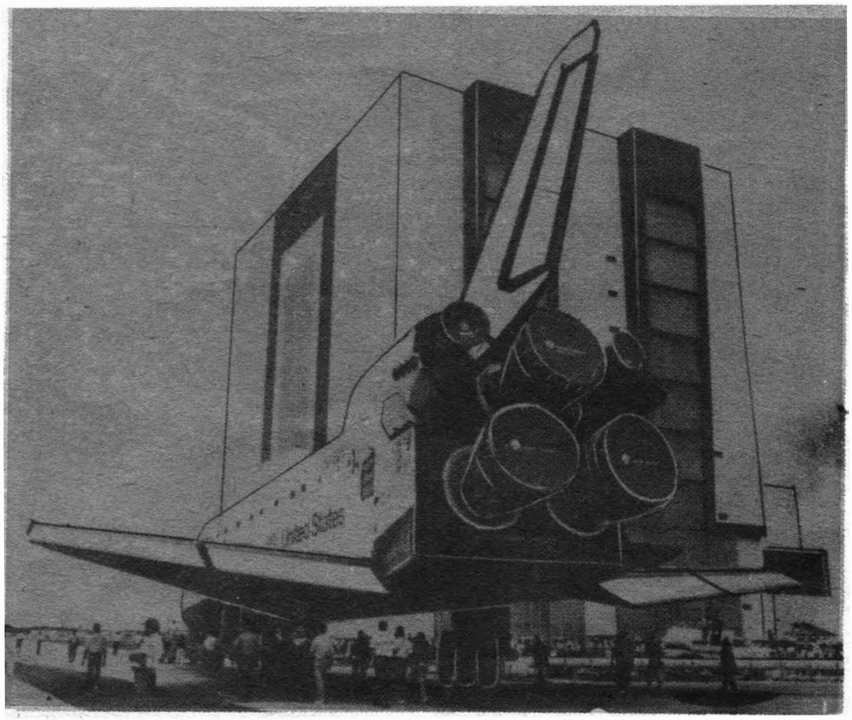
4 August
The first Flight Readiness Firing attempt was aborted just before main engine ignition.

10 August
The FRF was successfully conducted at 7:30 EDT after a faulty fuel bleed valve was replaced.

18 August
The Production Verification Motor(PVM)-1 test firing was successfully conducted in the Utah desert.

29 August
The Tracking Data Relay Satellite and IUS upper stage was placed within Discovery's payload bay.

June 21 1988: Discovery during transfer to the Vehicle Assembly.
NASA



OV-

A Replacemen

A Photo Essay

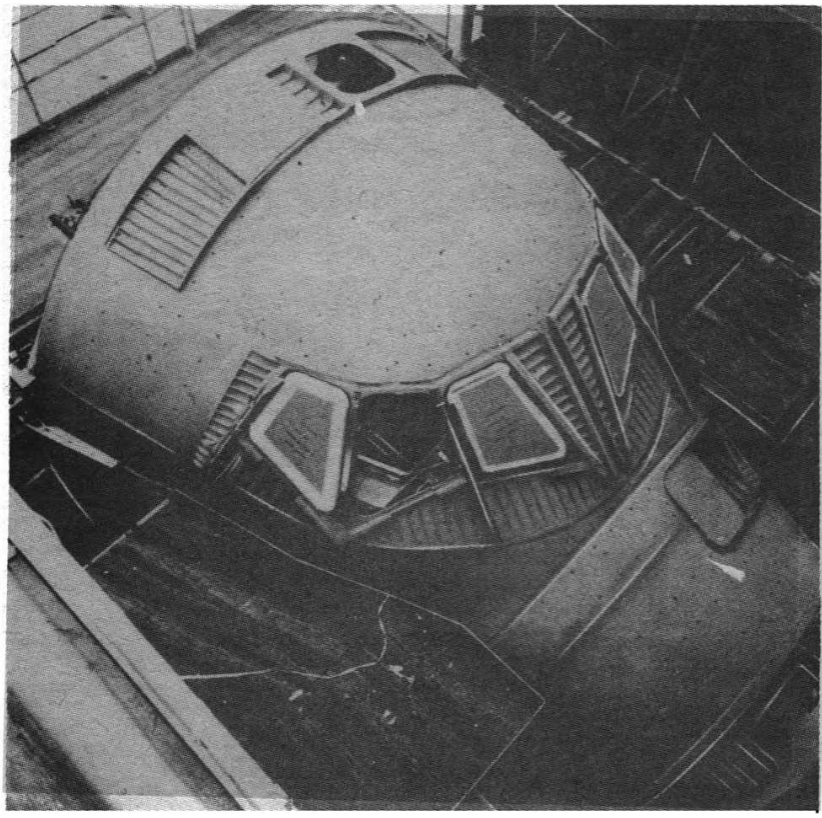


PHOTO A: The completed outer shell of the crew compartment awaits fitting of internal structures. *Rockwell International*

Major structural components of the planned replacement for the Space Shuttle Challenger are currently in the process of assembly at two Rockwell International facilities in the State of California. Construction began on OV-105 (as the new orbiter is currently designated) in August 1987.

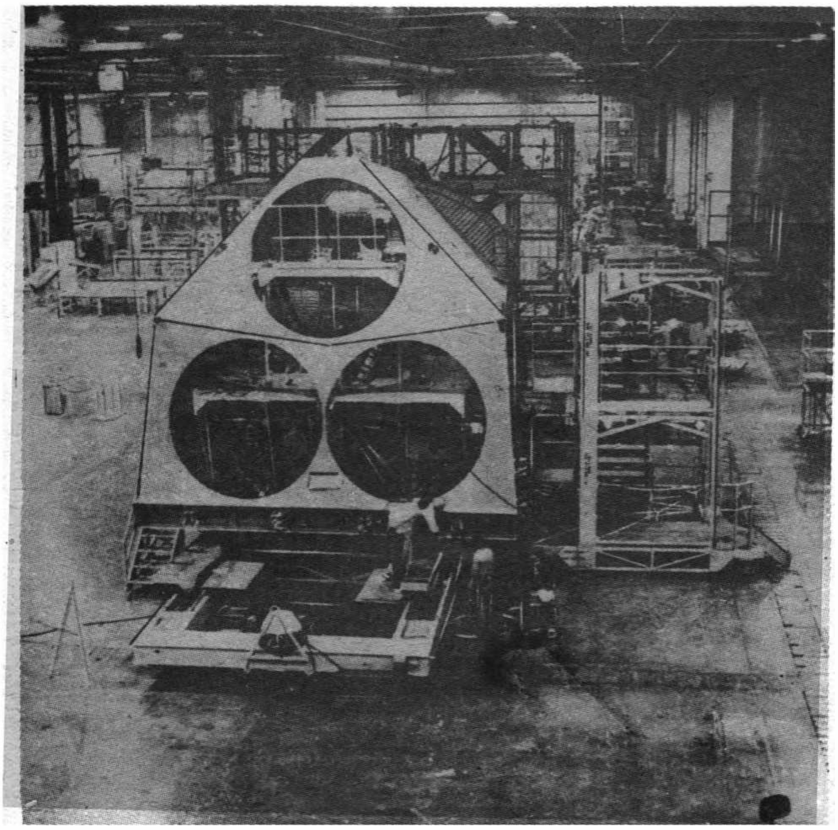
The majority of the components for the replacement orbiter were actually ordered by NASA from Rockwell in 1983 as structural spares to be used in case of an accident with an existing orbiter.

The crew compartment and the aft fuselage (engine compartment) sections are presently on the factory floor at the Rockwell plant in Downey – Photos A, B and C.

While the orbiter wings and mid fuselage (cargo bay) are being assembled in the main Rockwell plant in Palmdale – Photos E and D.

Final intergration of all the compo-

PHOTO C: The aft fuselage of the new orbiter. *Rockwell International*



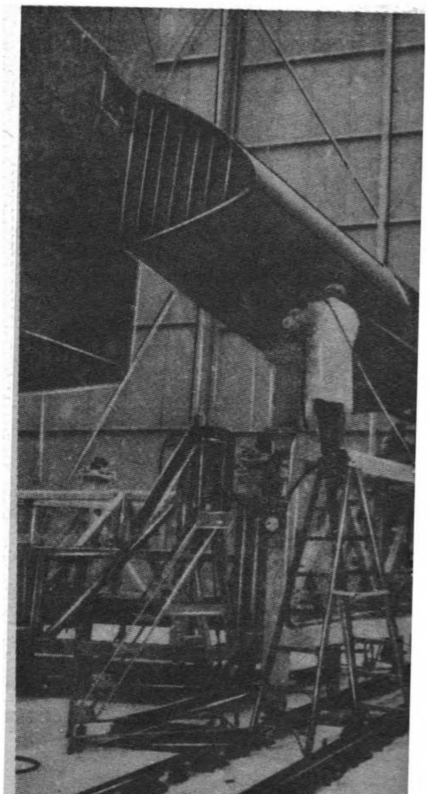


PHOTO D: Part of the left wing of t
ment tool at Palmdale.

:] 105

! for Challenger

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nents into the finished orbiter will be performed at Palmdale with completion of the orbiter in April 1991. The maiden launch for OV-105 is currently scheduled a year later in April 1992. The cost of the painstakingly hand-crafted space ship will be at least $1.2 billion.

In addition to the main fuselage and wing components, a vertical tail, wing elevons, the body flap control surface and the EVA airlock are also on hand at the Rockwell plants. The payload bay doors are now being fabricated by Rockwell in Tulsa, Oklahoma. In September deliveries of individual components and the many shuttle subsystems were scheduled to begin arriving at the Rockwell plants from venders all across America.

American students will compete nationally to name the replacement Space Shuttle, scheduled to make its first flight in 1992.

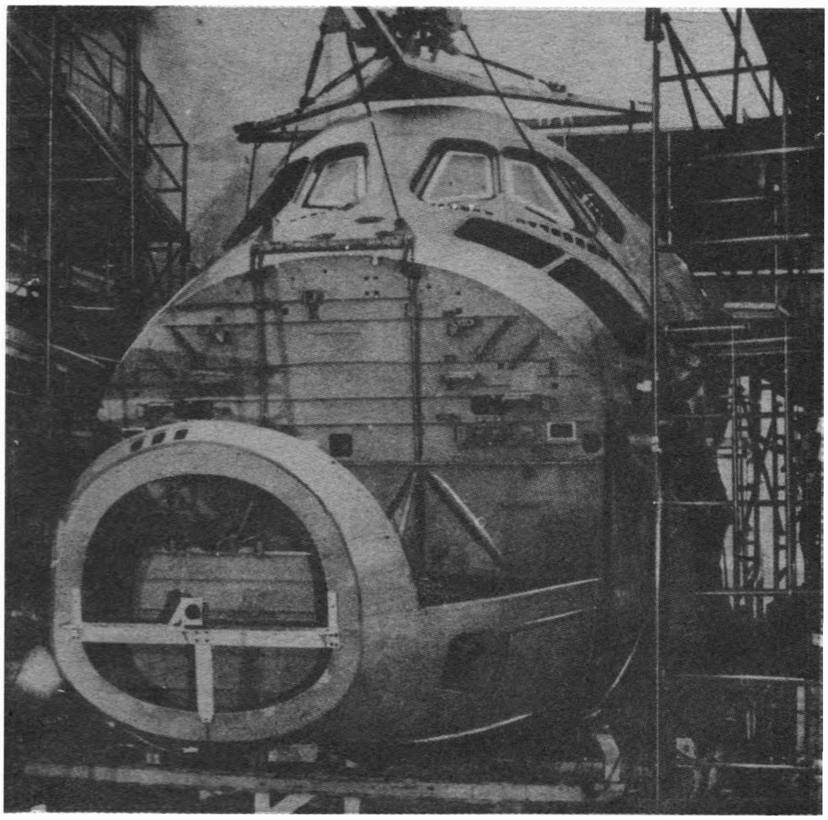
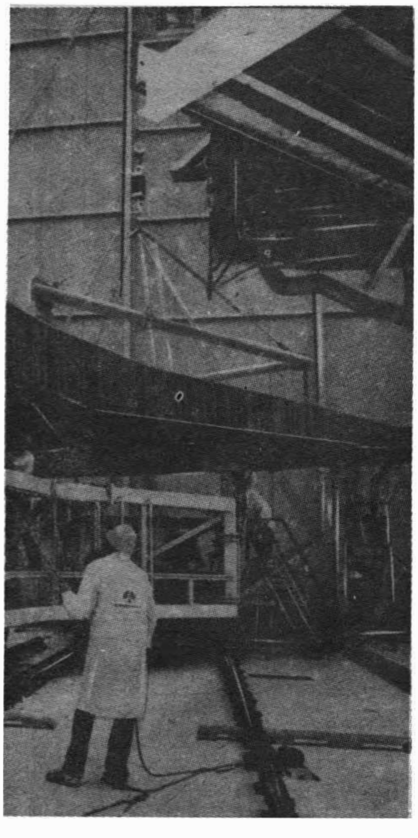
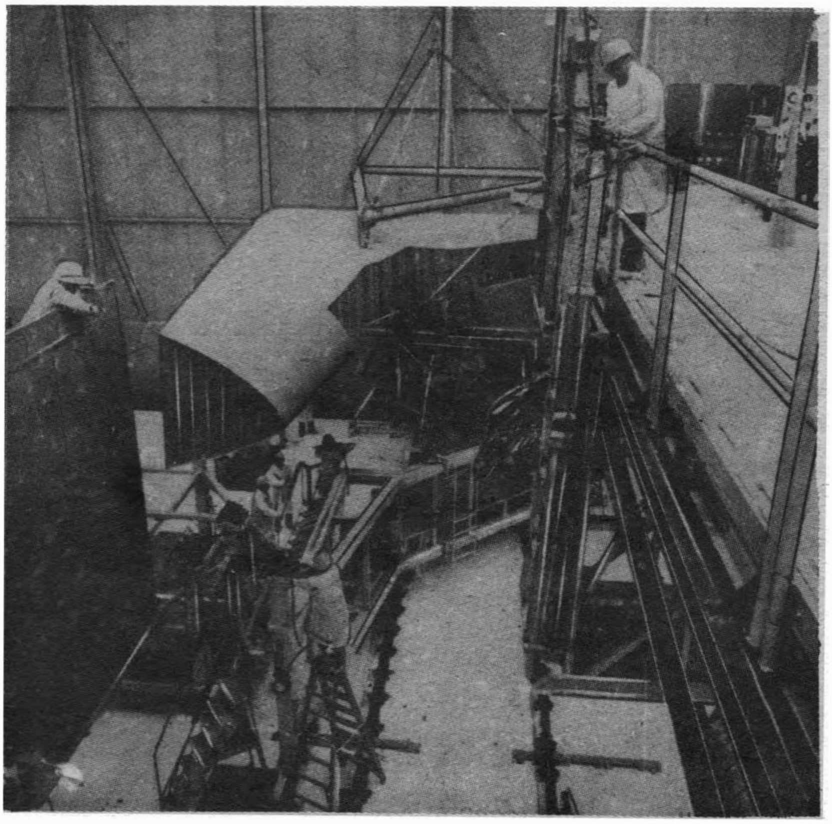


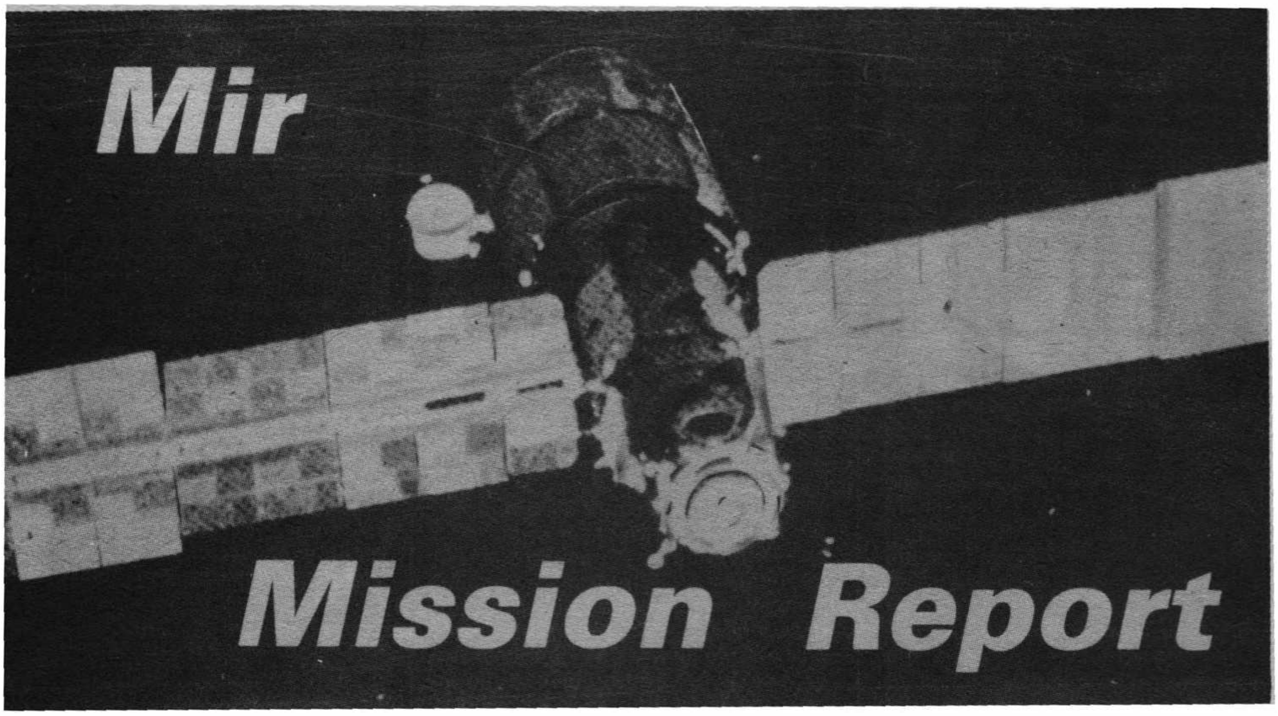
PHOTO B: **Mating of the outer and inner bulkheads of the shuttle's crew compartment.** *Rockwell International*



: crbiter is fitted into the assembly align- *Rockwell International*

PHOTO E: **View from above of left wing being fitted into alignment tool.** *Rockwell International*





Soviet cosmonauts Vladimir Titov and Musa Manarov are spending their tenth month in orbit onboard the Mir space station. *Neville Kidger* reports on the continuing research programme, the ten day Soviet-Bulgarian mission and an attempt to repair a British/Dutch telescope during a daring spacewalk.

Future Plans

The build-up to the traditional celebration of Aviation and Cosmonautics Day in the Soviet Union – April 12, the date of Gagarin's flight – was marked by a lack of reports about the activities of the two cosmonauts continuing the permanent occupation of the Mir orbital complex, Vladimir Titov and Musa Manarov (Call-Sign "Okeans").

However, at a press conference at the Flight Control Centre near Moscow, Viktor Blagov, a deputy flight director said that up to that point the two men had conducted some 330 experiments during their stay on the station. Of these 276 were devoted to astrophysics with particular attention being given to the activities of the Supernova 1987A which was still of great scientific interest.

Blagov said that Mir would have four specialised modules docked to it, the first arriving "at the end of the year." Another module would follow six months later and the third and fourth the following year. The rapidity of these additions would allow the station to retain symmetry. All the modules would be launched by Proton rockets.

The first module would be primarily an airlock (which would also feature manoeuvring units for the cosmonauts to use outside), the next would be another astrophysics module and the third a materials processing module which, in Blagov's opinion, should be allowed to fly free for long periods and then redock with the complex so that its payload of processed materials could be retrieved. The final module would be a dedicated life sciences one which, according to other sources, will feature a sterile area and an airlock.

The total weight of the Mir complex after these additions would be over 100 tonnes.

Large crews of up to 12 specialists may be flown into space and would relieve cosmonauts of the duty of being "all-rounders" in science work. The presence of such large crews would require a considerable increase in food supplies and other cargoes, Blagov admitted.

Meanwhile, in orbit, the cosmonauts were reportedly falling behind in their work due to the conflicting demands of the many various specialists all of whom wished their work to take priority.

Towards the end of April the two men conducted more experiments with the processing units such as Pion-M and continued regular working cycles with the Kvant X-ray telescope battery and the other Kvant instruments. Observations of the Earth were also a major part of the work with the men taking pictures of Cuba as part of a remote sensing exercise.

Progress 35 Departs

By May 3, the two men were loading up the Progress 35 cargo craft for its undocking. On April 22, the engine of the cargo ship had corrected the orbit of the complex, placing the complex in a 91.4 minute orbit at a height of 366 x 340 km. At 0136 (all times GMT) on May 5 Progress 35 was undocked from the complex and sent to destruction in the atmosphere at an undisclosed time shortly after.

Over the next few days the cosmonauts continued their Earth observations and astronomical work with TASS reporting that the men were taking UV pictures with the Glazar telescope on Kvant of individual constellations.

Progress 36 in Orbit

At 0030 on May 13 the Soviets lofted Progress 36 into orbit from the Baikonur Cosmodrome. It docked with the Kvant side of Mir at 0213 on May 15 to continue the remarkably successful series of automatic dockings in the Salyut/Mir programmes. The cosmonauts began to unload the craft shortly afterwards.

The craft had delivered "a considerable amount" of scientific equipment for the upcoming Soviet/Bulgarian mission, due to start on June 7.

On May 17 the external service of Radio Moscow said that the two men were to conduct an EVA in late May to inspect the Roentgen observatory on Kvant and, if necessary, replace parts. There had been an earlier report that the UK's TTM telescope was experiencing difficulties that an EVA would be needed to resolve them.

During the following days the cosmonauts spent much time unloading the equipment delivered by Progress. It was also reported that the amount of entertainment and sports programmes that were beamed to Mir were being increased at the request of Titov and Manarov.

On May 26 they reported that the equipment for the joint mission was being set up so that the crew of the Soviet/Bulgarian mission could get straight to work. On Earth, on the same day the two crews for the flight flew to Baikonur for final preparations for the flight.

By May 31 the EVA had not occurred and a TASS report on that day made no mention of it. Instead the men were to refuel the station with fuel delivered by

Progress, use the Svetoblok-T plant to synthesise a polycrylamide gel (used to upgrade technology for production of biologically active substances on Earth) and tend their biological installations in which wheat seeds and tissue cultures of the arabidopsis plant were growing.

On June 3 Progress 36's engine corrected the flight path of the complex in readiness of the joint flight and, at 1112 on June 5 the cargo ship was undocked and deorbited at 2028 the same day.

Soyuz TM-5 Joint Flight

Moscow TV gave long and detailed coverage to the preparations for, and the launch of, Soyuz TM-5 with two Soviet and one Bulgarian cosmonaut.

Indeed, the launch pad itself was shown with several advertising placards around it, all part of the Soviet's commercialistion of its international spaceflights.

A TV correspondent revealed that the pad had seen 289 launches to date, as witnessed by the stars on the launch gantry. (The 289th had also been seen on TV – an international corps of TV reporters from all over the world, numbering 76, had flown to Baikonur on May 18 and had been shown the town of Leninsk and several areas of the Cosmodrome, including the Energia and Shuttle preparation buildings and the Energia launch pads. They were shown the launch of Cosmos 1944, a "topographical" satellite on a Vostok booster before leaving. That was launched from the same pad that the Bulgarian mission would start from, they were told).

The State Commission, chaired by Kerim A. Kerimov, sat at 1000 on June 6 to select the prime and reserve crews. The meeting was attended by many journalists and Kerimov said that the 46 experiments in the "Shipka" programme required some two tonnes of equipment. The flight would last for 10 days.

The prime crew was announced as Anatoli Solovyov and Viktor Savinykh of the USSR and Aleksandr Aleksandrov of Bulgaria – the "Rodnik" (Spring) crew, and the reserve crew – Vladimir Lyakhov and Aleksandr Serebrov of the USSR and Krasimir Stoyanov of Bulgaria – the "Proton" crew.* Launch was confirmed for June 7.

The TV coverage of the launch itself showed the suiting-up and walk-out to the bus which took the men to the launch pad with Kerimov saluting them off. It even had two outside broadcast centres in Bulgaria – one in the capital Sofia, the other in Omurtag, Aleksandrov's home town where his mother and other family members watched events on an outside TV set.

Solovyov, Savinykh and Aleksandrov boarded Soyuz TM-5 at 1145. The Soviets had earlier said that launch was scheduled for 1403. Just one minute before this the Soviets broadcast pictures from inside the launch control bunker showing the controllers in front of TV screens and other monitoring equipment and a controller looking through a periscope.

Launch came precisely on schedule and the TV was able to follow the ascending rocket to high altitude. It was the 290th launch from the recently dedicated "Gagarin" complex from where the first flight began in 1961. Shortly after insertion into orbit it was reported that soon the ship's aerial and antennae were to be deployed as well as the solar panels. The spacecraft would begin to spin to follow the Sun to provide power.

The spacecraft and station were being monitored by the Moscow Flight Control Centre (FCC) and a Bulgarian tracking centre at Stara Zagora which provided information to the Soviet centre. This allowed ballisticians at FCC to better compute the trajectories of the two space objects.

Docking was scheduled for 1555 on June 9, it was revealed. Cosmonaut Oleg Makarov said that the two-day slower approach to the station allowed greater accuracy for approach but that great care was involved. He said that the approach was worrying because problems had arisen in the past, an obvious reference to the Soyuz 33 approach which was abandoned when the engine of the spacecraft shut down after 3 seconds of the 6-second-long final approach burn. That flight featured the first Bulgarian cosmonaut Georgi Ivanov and the possibility existed that he, and fellow crewman Soviet Nikolai Rukavishnikov, could have been marooned in orbit. The Soviet crewman admitted to being "scared as hell" when the failure occurred.

Thankfully for the two men the back-up engine worked successfully and the two men made a highly stressed reentry to land on April 12, 1979 just two days after their launch. Even then the cosmonauts had to manually shut off the back-up engine when it burned beyond the planned 188-second duration.

The Bulgarian mission was the only failure during the 9 Intercosmos flights to the Salyut 6 space station provided for under a 1976 accord. The accord for the Soyuz TM-5 flight was signed on behalf of the new Soviet space coordination agency Glavkosmos. Continuity was being provided by Aleksandrov's presence - he was the reserve to Ivanov in 1979 and has since become deputy director of the Bulgarian space centre of that country's Academy of Sciences.

Following the first orbital correction Soyuz TM-5 was left in an orbit of 343 x 282 km, period 90.7 minutes, overnight. The Soviets said that by its 33rd orbit Soyuz would be some 40 km from Mir with docking scheduled on the next orbit. The approach would be automatic and it would culminate with a fly-around Mir at a distance of 50 metres.

Docking was covered in a live relay in which the approach to Kvant could be clearly seen. However, it was reported that the Kurs (Course) automatic docking system had failed to provide the correct information and caused confusion in the FCC. Soyuz had deviated slightly from its intended course. Controllers interrogated the ship's systems and corrected the error. The approach was completed with the docking occurring at 1557, although by that time Soviet TV had ceased its scheduled broadcast. The spacecraft were tracked shortly afterwards in a 355 x 349 km orbit with a period of 91.5 minutes.

The three visitors crossed into Mir and were warmly welcomed by Titov and Manarov under the gaze of TV. It was the two men's first physical human contact with other people in almost six months.

Working in Space

One of the first jobs on June 10 was the transfer of seats from Soyuz TM-4 to TM-5 and vice versa. The Rodniks were to return in the older craft leaving Titov and Manarov their newer ship.

During their first day of joint work Soviet TV showed an irritated Titov holding some rubber straps up to the camera and saying that he had requested them to have clasps on. He asked sourly what the men were supposed to do with these straps without clasps. Soviet TV said that in the past the authorities had been "shy" about such exchanges between cosmonauts and controllers but that this was now changing.

A more welcomed gift for the residents was an orchid which had been grown onboard Mir before being returned to Earth. There it had been stolen from the institute where it was kept but was finally recovered and the thief apprehended.

Also, during their first full day on the station, the visitors spoke with Bulgarian leader Todor Zhivkov over a TV link. The conversation was shown on Soviet TV the next day.

Bulgarian Experiments

The programme of medical experi-

*It is unknown why the Soviets replaced Andrei Zaitsev by Serebrov in the reserve crew. Also, Lyakhov is to fly to Mir on Soyuz TM-6 with Dr. Valeri Poliakov and A.A. Mohmand of Afghanistan. Poliakov is to stay on Mir with Titov and Manarov. Reserves for the August 29, flight are Soviets Anatoli Berezovoi and Dr. German Arzamzov and Afghan M. Dauran. Lyakhov and other cosmonauts such as Volkov, Viktorenko and Berezovoi have also trained as solo Soyuz TM rescue pilots, the Soviets say.

ments covered three basic areas – physiology, psycho-physiology and radiobiology.

In the Prognoz (Forecast) experiment the aim was to assess the cosmonaut's operational qualities. The experiment would also help in applications for lorry drivers and chemical and power station operators, the Bulgarians said.

Original Bulgarian methods were used in the Potential experiment to study the nervo-muscular system of the body and the Stratokinetika test was related to studies of the body's movements in weightlessness.

The Zora experiment employed a set of equipment called Pleven-87 to study locomotor functions and volition processes. The equipment used microprocessors to collect and process data and will be a permanent fixture on Mir as much of the Bulgarian equipment will be.

During sleep periods the cosmonauts' electrophysiological signals were recorded on a cassette tape which ran at a slow speed. The tapes of the Son experiment each lasted for 24 hours.

In the Earth observation programme the men conducted visual observations of Bulgarian territory although they were hampered by large-scale persistent cloud cover. The Bulgarians had developed a new multi-channel spectrometer with 256 channels for the study of the atmosphere. This was used extensively during the week. It was the follow-on to the Spektr-15 spectrometer which had been used on the Salyut stations since 1979 and which featured 15 spectral channels.

In the programme for materials processing the men used Mir's furnace to obtain alloys of aluminium-copper-iron under the Strukura code name and also produced alloys of aluminium and tungsten and aluminium-copper and tungsten. In the Klimet-Rubidium experiment the men used a device to develop the technology for producing very light batteries and condensers with a mixture of rubidium, silver and iodine. Electrophoretic experiments used the Ruchei plant to separate out and cleanse genetically engineered interferon

A key item of the flight was the use of the Bulgarian-made Rozhen astrophysical instrument, the Paralax-Zagorka image intensifier and the Therma impulse photometer. Rozhen was being used to examine the possibility of developing an autonomous astronomical complex which would become a permanent feature of the Mir station and unmanned satellites. The instrument was used to study stellar objects and the survey results are to be analysed aboard the complex.

MIR MISSION REPORT

Neville Kidger

One of the final experiments conducted was a study of the recreational time of the men. In the Dosug experiment the impact of music and video programming, as well as computer games, on the crew's work and morale was studied.

Throughout the flight the visiting crew did not perform any physical exercises, as the main crew continued their daily routine. However, there was time off for Aleksandrov to entertain the children of Bulgaria with a small puppet in a TV report!

On June 16, the cosmonauts conducted their experiments in an abbreviated form to allow them more time. Whilst Aleksandrov conducted more medical work Solovyov and Savinykh packed results, samples and computer discs into the Soyuz TM-4 descent cabin ready for their return to Earth the next day. About 30kg of results were transferred into the capsule.

Return of the Rodniks

Before entering Soyuz TM-4 for the return to Earth, early on June 17, the five men gave short speeches to the television audience. Soyuz TM-4, with Solovyov, Savinykh and Aleksandrov, undocked from Mir's front axial port at 0618. Retrofire lasting 216 secs occurred just before 0930 and atmospheric entry was at 0950. In eight mintues the height dropped from 100 km to 10 km before the single main parachute opened.

Soviet TV carried a live broadcast from the FCC but had no pictures of the actual landing at 1013, some 202 km from the town of Dzhezkazgan, until the reporters sent in their video tapes some time later.

At the landing site, a dried-up lakebed, the temperature was 42-44 degrees C in the shade! The wind blew at an average of 6 metres/sec causing problems for the ground rescue teams. When they tried to erect the medical examination tent it turned into a balloon and, despite efforts from all around, turned over. To make matters worse, the hatch of the descent module stuck at first.

Solovyov's first remark was "Isn't it torrid here on Earth!" as he was helped out of the cabin. He and Aleksandrov sat on the ground as Savinykh claimed the only chair available.

The Flight Engineer described the landing, his third, as the smoothest yet. The two other men revealed that they were experiencing some discomfort.

The recovery problems continued to the end – fearing a sandstorm in the wind the rescue teams decided to halt the plan to use a helicopter to load the descent cabin onto the back of a recovery truck until it subsided.

The cosmonauts, meanwhile, were flown first to Dzhezkazgan and then to Baikonur where it was revealed that the two new cosmonauts were feeling "somewhat worse" than had previous crewman on their first short trips into space.

At a press conference later Solovyov said that he had felt some discomfort upon first entering space but by the third or fourth day he felt as though he had unlimited control over his body. Aleksandrov revealed that at the moment of landing he felt a sudden loss of control over his leg muscles but felt stronger in his arms. A strength test on June 18, showed him to be 50 per cent stronger in his right arm. He had not slept well on that first night back on Earth feeling that the pillow was uncomfortable.

Savinykh later complained that the duration of the flight was too short. His comments were answered by Glavkosmos official Stepan Bogodyash who said that the duration was determined by the volume of work prepared by the Bulgarian side.

The official also said that Titov and Manarov had not yet been set the task of bettering Yuri Romanenko's 326-day record flight.

Orbital Repairmen

On June 18, Titov and Manarov entered Soyuz TM-5 and undocked from the aft port on Kvant at 1011 to perform the new routine redocking operation. After Mir had been commanded to rotate 180 degrees, TM-5 was redocked with the front axial port at 1027 thus freeing the rear port for use by future cargo craft.

After a two-day rest, their first for a fortnight, the cosmonauts set about preparations for their next major task – the in-orbit repair, during an EVA, of the British/Dutch TTM shadow mask X-ray telescope on the Roentgen observatory mounted on Kvant.

The controllers had noted sporadic failures of the telescope late in 1987 and decided to effect a replacement of the detector which would require a new one being flown to Mir and replaced during as EVA. The repair work was compared in the West with that done by the Shuttle 41-C crew on the Solar Max satellite in April 1984.

However, there were important differences in the tasks. The Mir crew had not trained for such an operation and the detector was not designed to be replaced in orbit. For this reason the two men were sent a video tape of Earth-bound cosmonauts performing all of the operations in the water tank at Star Town and also spoke with these cosmonauts.

British and Dutch specialists were also on hand at the FCC for the operation which was to take place on June 30. The timing was dictated by the need for long periods of sunlight in orbit. The necessary tools and equipment were delivered on Progress 36.

On June 30, the hatch of one of the four radial docking ports was opened and Titov and Manarov, hauling 40 kg of equipment with them, began inching their way along the length of the Mir/Kvant spacecraft, a distance of almost 20 metres. The equipment was carried on a special platform. A ramp was used to cross from Mir to Kvant.

Once at the site of the Roentgen observatory the cosmonauts' first task was to slice through the 20-layer thick thermal blanket. This exposed the telescope's detector unit. However, even at this stage the men were experiencing delays in their schedule, which gave them four hours to complete the work (the space suits have a duration of five hours use).

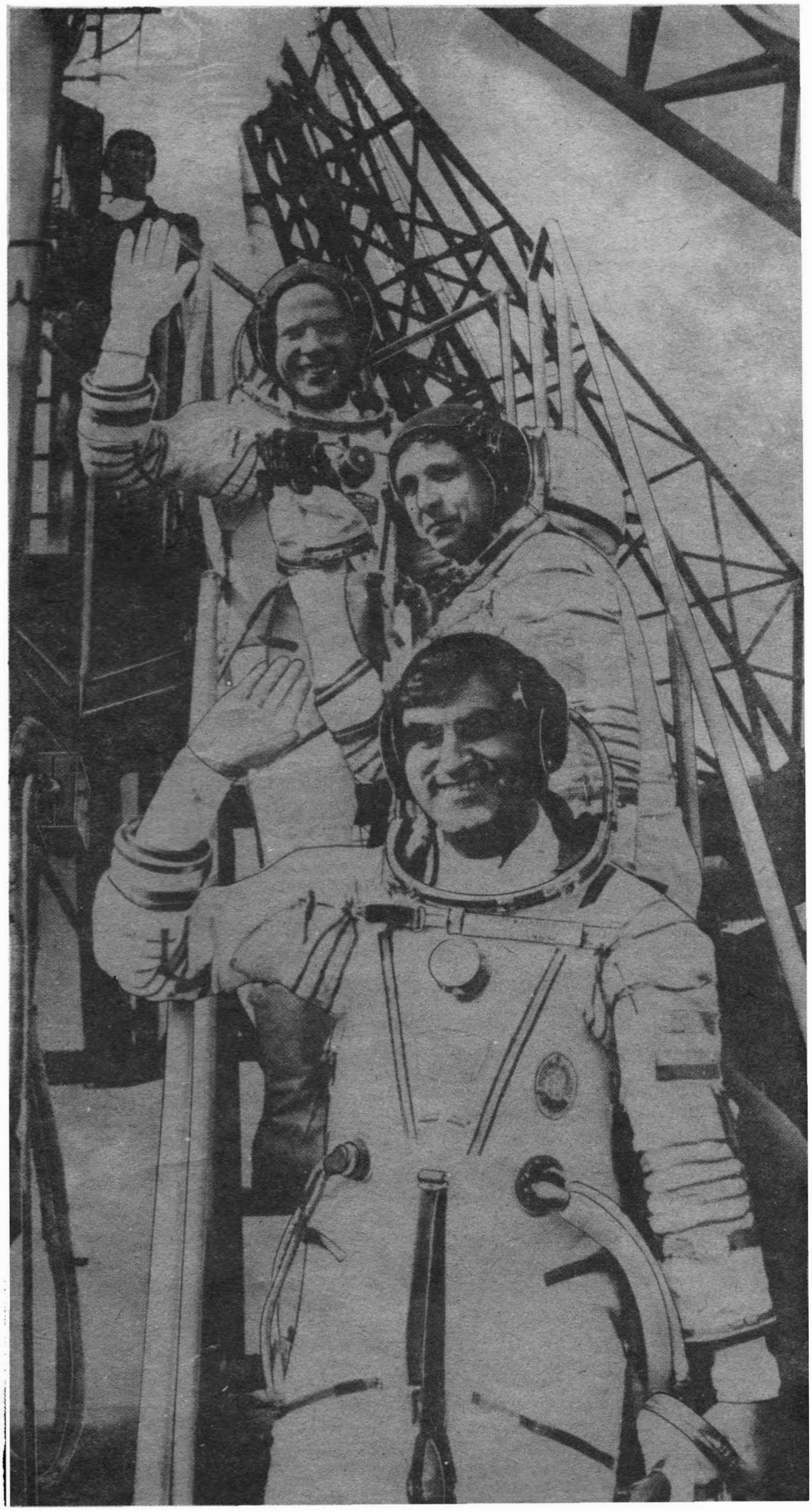
The Soviets described the task as "arduous" and several times the men asked permission to stop and rest. Problems were also experienced in securing their feet to remain steady. They took turns in holding each other. Small bolts proved difficult to remove with their bulky gloves. In order to free the detector these bolts and a brass clamp had to be removed. The removal of the screws took 1½ hours when only 20 minutes had been allocated for the task.

Finally, with the work overrunning and controllers worried about the men's supplies, the wrench which the men were using to lever off the clamp snapped. With the clamp still in position controllers told Titov and Manarov to return into Mir for the task to be reassessed. Manarov installed a new piece of thermal insulation to patch up the area. After five hours 10 minutes of unfinished work a disappointed crew ended their EVA, having completed 70 per cent of the task.

At FCC Dr. Gerry Skinner, on behalf of the scientists of Birmingham and Utrecht said he was "very dissappointed."

It was later reported that new tools and equipment would need to be manufactured and flown to Mir for the task to be completed. By late July the Soviets were talking about mid-September as the time when the next try would be made.

In the meantime the men continued their scientific work and, on July 20, received a new Progress cargo spacecraft.



The crew of Soyuz TM-5 (top to bottom) Anatoly Solovyov, Victor Savinykh and Alexander Alexandrov.

Novosti

Soviet Space Programme

Keen interest in Soviet space activity is reflected in correspondence to* Spaceflight *and is benefitting from the new Soviet policy of openness.

Soviet Lunar Missions in the Next Decade

Sir, Thanks to the information now available on new Soviet launchers and on the earlier intended Soviet lunar landing programme (described in the "Soviet Astronautics" issue of ***JBIS*** March 1988), one can put together a reasonable scenario for a manned Soviet lunar programme for the next decade.

The Energia launcher could put a Mir station with a dedicated lunar geophysics module and a Soyuz spacecraft into lunar orbit.

A second launch could involve a large lunar lander for a long-term stay on the surface with another Soyuz spacecraft which could dock with the lunar orbiting complex for some time before a lunar landing is made. Five cosmonauts could work aboard the complex, three of them subsequently landing. Progress type vehicles can be sent to lunar orbit with a three-stage version of the SL-16, thereby bringing supplies to lunar orbit. Another type of cargo ship could supply the landing crew either directly from Earth as in lunar landing missions or from the lunar orbiting laboratory.

It should be possible to keep the cost for such a lunar exploration programme relatively low, since the hardware involved is proven and Energia and SL-16 launches give a very good cost per kg rate.

In an interview with General Shatalov on Radio Moscow, May 20, Soviet interest in the Moon was stated to precede a manned expedition to Mars.

M.Q. HASSAN
Baghdad

Soviet Planetary Missions in 1990's

Sir, Following the Project Phobos report (***Spaceflight***, July 1988, p.272) and other articles concerning possible future Soviet exploratory missions, a schedule of 1990's launches could be:

1992	Mars Observer
1993	Moon Observer
1994	Mars Rover/Balloon Sonde/Penetrator/Film Capsule-Return probe
1995	'Corona' Sun Observer via Jupiter flyby
1996	Moon Sample-Return probe
1998	Mars Rover/Sample-Return probe
1999	Jupiter/Saturn mission with Titan probe

An asteroid sample-return mission, and unmanned laboratory/rover probe to the Moon are also likely candidates before the year 2000.

Given these outlined missions, some arguments might be put forward as to their detailed components:

Firstly, the 1992, '93, '94, '95 and '99 missions, and the asteroid sample-return probe will probably make use of developments of the Phobos modular spacecraft design. The '94, '99 and asteroid missions would be equipped with re-entry/landing craft, and small film/sample-return capsules used for the '94 and asteroid probes. The '94 Mars mission could be a very useful rehearsal for the 1998 Mars probe.

Secondly, the requirements of the '96, '98 and unmanned laboratory/rover missions would appear to necessitate use of the Energia launch vehicle with a strap-on cryogenic third stage to launch 20 to 30 tonne probes to lunar and planetary orbits. The 1996 Moon Sample-Return probe would probably test the Rover/Ascent-Stage/Return-Capsule components of the 1998 Mars Sample-Return mission, as well as possibly employing a development of the 'space-tug' from the Cosmos 1686/Kvant design as a 10 tonne descent stage.

All these possible developments show continued Soviet use of existing and standardised components, as well as indicating a capability to rapidly develop a manned presence in orbit and on the surface of the Moon in the event of the USA seriously planning a return there early next century.

PAUL J. MANT
East Sussex, UK

A Case of Mistaken Identity

Sir, Over the years, there have been many reports in the West supposedly identifying previously unknown Soviet cosmonauts.

These reports were especially prevalent during the early years of the Soviet manned space programme, and many have since been debunked. Some were more persistent however, having an air of authenticity about them. One such story appeared in 1979,

According to the report [1], two space-suited men had been pictured in the May 1977 issue of *Aviatsiya i Kosmonautika*, and had been identified as "officers S. Barsukov and K. Bondarev". The assumption was made that they were both cosmonauts attached to the military Salyut programme i.e. Salyuts 3 or 5. This assumption has gone unchallenged for nearly 10 years.

However, following the publication of my book about the Soviet manned space programme [2], many readers have contacted me with new information, and I am now able to state categorically that Barsukov and Bondarev were NOT cosmonauts.

One reader contacted the head of the cosmonautics office at *Aviatsiya i Kosmonavtika*, V. Gorhkov, to query the story. He replied: "Indeed, in May 1977 our journal published the article and the photograph of two spacemen dressed in space suits. One of them is A. Yeliseyev, the second is unrecognisable. There is no title to the photo."

He continued: "The introduction to the article said, Officers S. Barsukov and K. Bondarev ask the journal to recount how cosmonauts participate in the creation of spacecraft and orbital stations'."

The identification of the two men as cosmonauts therefore, was a result of poor translation! We can therefore now erase Barsukov and Bondarev from the ranks of the cosmonaut team – they never really joined.

Having solved one mystery, I would now like to pose another.

It has always been thought that there were support crews for nearly every Soviet manned space flight, but there have been occasions when these appeared to have been dispensed with. One example was the Soyuz 10 and 11 missions to Salyut 1.

However, in June 1988, nearly 17 years after the death of the Soyuz 11 crew, Vitaly Sevastyanov has revealed that he was a member of the third (i.e. support) crew for Soyuz 11 [3].

Are any readers aware of the names of the other members of the support crew – Nikolayev must be a firm favourite as commander – or have any evidence to substantiate my own feeling that there was only one support crew for both Soyuz 10 and Soyuz 11?

GORDON R. HOOPER
Lowestoft, UK

References

1 Correspondence, ***Spaceflight***, Vol 21, April 1979
2 *"The Soviet Cosmonaut Team A Comprehensive Guide to the Men and Woman of the Soviet Manned Space Programme"* GRH Publications 1986
3 *"Man, The Earth, The Universe"* Soviet TV, June 11, 1988

CORRESPONDENCE

Soviet Launcher Designations

Sir, I am confused by Soviet launch vehicle designations, even though recent correspondence (***Spaceflight***, March 1988, p.122) attempted to clarify the issue. As far as I can tell the Soviet satellites Protons 1 to 3 were not launched by the D-1 (SL-9) but by the 'D-0'. In some sources the launch vehicle of the first three Protons was stated to have had only a two stage central core with the six side-mounted rockets being used as the first stage. The core was ignited at altitude.

With all other launches, including Proton 4, the core has been increased to a three stage system and the six side-mounted rockets act as boosters (the rocket though is still a three stage system). Both the Sheldon and the SL-coding systems cannot describe these variants of the D rocket. Such variations as those comply with Phillip S. Clark's findings as stated in ***Spaceflight***, February 1987, p.48.

Also what happended to the F-1-r, the F-1-m and the D-2?

Both the Sheldon and the SL-designations should either be completely revised or replaced, as 'A-0' (SL-1) and 'A-0' (SL-2) are identical for example!

I find the exploration of space a highly fascinating subject and I would be lost without the BIS ***Spaceflight*** publication.

JOHN CHRISTOPHER
London, England

Mr. Phillip S. Clarke replies:

The launch vehicle designations used in the West for Soviet boosters can be confusing since they were devised during the 1960's when far less was known about the vehicles than we know now.

The "SL-" system was probably devised in the third quarter of 1965: this is because all of the SS-6/Sapwood derived vehicles known to have flown in mid-1965 are grouped together as SL-1 to SL-6 and the subsequent boosters were listed in the order that they first flew. The SS-6 derived SL-10, which flew in December 1965, is therefore out of order as far as the main SS-6 grouping is concerned.

Sheldon's system was first published in Autumn 1967 and therefore reflects the vehicles known *or suspected* to that time, grouped by the first stage.

Of course, with the passage of time, ambiguities in both systems have come to light. In the "SL-" system, SL-1 was applied to Sputnik 1 and SL-2 to Sputnik 3 because the DoD researchers could not believe that the same basic vehicle was used for initially an 83.6 kg payload and then a 1327 kg payload. We now suspect that the first and second stage (or both parts of the one-and-a-half stage combination – classify the profile as you will) engines were up-rated between these missions, so on this basis the two designations could be justified. However, the two variants of the Vostok booster – the original Luna version and the Vostok itself – still fall under the SL-3 designation although the upper stage RO-7 engine was up-rated for the manned programme.

Since the flight of the first SL-9 vehicle in mid-1965, new "SL-" designators have been added in chronological order of the first successful flight to orbit with one exception: in the mid-1980's the SL-15 designator was given to the abandoned giant booster of the late 1960's. If it had been designated in order it would have been the SL-14 vehicle, this designator now applying to the three-stage Tsyklon booster.

With Sheldon's system, one has the problem of "when is a rocket stage not a rocket stage?" For example, was the Saturn-1B/Apollo CSM a two or three stage vehicle? There were of course two stages, because the service module was an integral part of the Apollo spacecraft. Yet in the Sheldon system we have "F-1-r" and "F-1-m" where the payloads had apparently different manoeuvring systems ("r" and "m") but the same basic two-stage SS-6/Scarp booster was used. These two variants are classified by the DoD with the single SL-11 designation.

Turning now to the Proton. Apparently every analyst in the public domain, as did Charles Vick in his 1973-1974 ***Spaceflight*** papers, described the lower part of the vehicle as having six strap-ons and a central core which either ignited on the ground or at altitude. It was thought that the Proton might simply have been a larger version of the SS-6 design. It was not until the third quarter of 1985 that it was realised by John Parfitt and Alan Bond that this was incorrect and the first stage was assembled like the first stages of the Saturn-1 and Saturn-1B vehicles, with normal tandem staging. We now know that this view is correct and that the earlier reconstructions (including my own, published in September 1977) are incorrect.

The correct variants of Proton are:

SL-9	D	First stage cluster of six engines plus tandem second stage.
SL-12	D-1-e	SL-9 variant but with new third stage added and a fourth Block-D stage.
SL-13	D-1	As SL-12 but without the fourth stage.

Other Proton variants like D-1-E-e, D-1-h and D-1-m which have been noted in Western literature do not and never have existed.

The suggestion that the Sheldon and "SL-" systems should be revised prompts the question 'when would one know whether the "old" or "new" designators were in use when reading such work'? Surely it is far better to use the existing systems while being fully aware of their limitations.

Soyuz Crew Changes

Sir, Recent events have moved me to add to my previous letter (***Spaceflight***, May 1988, p.192) on the subject of Alexander Serebrov.

With the launch of Soyuz-TM5 on June 7, 1988 an interesting crew change had taken place. Once more the Soviets had surprised us all by making a very late replacement of the backup flight engineer. Andrei Zaitsev was removed and had been replaced by Alexander Serebrov who himself had been replaced by Zaitsev in late 1987.

A photo was published in *Izvestia* (June 9, 1988) showing the Prime and Backup crews for the joint Soviet-Bulgarian mission to Mir. One small point of interest is the appearance of Serebrov who looks gaunt, probably due to an earlier illness that may have lead to his removal from the Prime crew in late 1987.

Recently I was handed another photo that confirms an earlier theory about Serebrov and Titov being the Prime crew for Soyuz TM2. The photo was published in a small Novosti Press booklet on Mir titled *'From Salyut to Mir'* 1987. The scene is aboard a recovery ship during water landing recovery training and can be dated around the winter of 1986/7. The photo shows Titov, Serebrov and Mohammed Fares. At the time of the photo these men had expected to meet in orbit the following summer.

Finally I would like a chance to respond to some letters to ***Spaceflight*** in the June 1988 issue.

M.M. Hughes asks why the orbital compartment of the Soyuz-TM is still used. The need is quite obvious to anyone who has taken a long plane ride. The small confines of the crew compartment does not allow much freedom of movement, which is required over the two day docking and rendezvous portion of every Soyuz-TM flight. As for the need for an extended crew compartment for a larger crew complement, I believe that is the purpose of the mini manned shuttle due in the 90's.

P.J. Parker mentioned that he believed that the 30 ton mini shuttle would fly on Energia. My understanding is that its launch vehicle would be the SL-16.

LEE ROBERT CALDWELL
Bristol, UK

Soviet Cosmonauts

Sir, I have the honour of relaying to you new information which I have just received from Mr. Yegupov, deputy of the Information Group at the cosmonaut centre in Starry Town, USSR. It deals with biographical data about Soviet cosmonauts involved in backup missions.

1. Yuriy Anatolyevich Ponomaryov has been identified as the backup Flight Engineer for Soyuz-18 in 1975 (with backup commander Kovalyonok). He was born in 1932 (no date given) in Chitinskoy Region. He is Russian and a member of the CPSU. In 1975 he completed the Ordzhonikidze Moscow Aviation Institute. He was selected in 1970 and left the programme in 1980 (for medical reasons, according to a separate letter from Yaroslav Golovanov. [If he was paired with Kovalyonok in 1975, the question remains why he did not fly with him in 1977-1978. He appears to have been in line behind Ryumin, Ivanchenkov, Andreyev, and probably Lebedev, so his turn just never came up].*

2. Georgiy Petrovich Katys has been identified as the backup engineer (for Feoktistov) aboard Voskhod in 1964. He was born in 1926; he is a Russian, and is not a Party member. In 1949 he completed Moscow Auto-Mechanical Institute and is a doctor of technical sciences. He was a member of the cosmonaut corps from 1964 to 1966. Earlier I was told he still works for the Academy of Sciences in Moscow. [Katys remained a "cosmonaut" well after the Voskhod mission, confirming other reports that Korolyov planned other Voskhod missions. Why Katys was not included in the 1966 engineer class is unclear; however, he was 40 and possibly considerd too old].

3. Pyotr Ivanovich Kolodin has been identified as a backup crewman on the Soyuz-6/7/8 mission (1969) and as a crewman for the 1971 Salyut-1 missions. His photograph has been published several times, and a retouched version with him removed has also been published. He was born September 23, 1930, no location specified, and is a Russian and a party member. He became a cosmonaut in January 1963 and left the corps in November 1986 (age 56!). [His precise role in the Soyuz-6/7/8 and Soyuz-10/11 crews remains confusing, as is any subsequent crew assignments in the Salyut-3/5 programme or elsewhere. He is still employed at Starry Town].

4. Aleksey Vasilyevich Sorokin has been identified as backup physician to Yegorov on Voskhod. He was born March 30, 1931; he was Russian and a party member. In 1957 he graduated from Saratov Medical Institute. From 1963 until his death on January 23, 1976, he was a doctor on the staff of the cosmonaut training center. His dates of cosmonaut service (particularly when he stood down) were not given. Golovanov in a recent letter to me identified him as a "military doctor" who died of a "blood disease". [It remains to be seen what connection Sorokin might have later had with any other doctor-cosmonauts from the mid-1960's, such as Rostislav Bogdashevskiy, identified to NBC-TV news in 1967 as a candidate cosmonaut. Was there a cadre of such specialists in the late 1960's that included both men and others?]

5. Aleksandr Yurevich Kaleri has been identified as backup flight engineer for the Soyuz TM-4 mission in December 1987. He was born May 13, 1956, in Yurmala in Latvia; however, his ethnic status is Russian. He is a party member. In 1979 he graduated from Moscow Physico-Technical Institute. He has been in the cosmonaut corps since February 1987. [The name "Kaleri" is not Russian, so perhaps his mother was Russian and his father Latvian (children may choose either parent's ethnic status – even though "Yuri" is not a Latvian name). And the 1987 date must refer to his completion of the 2-year candidate program, if he could then immediately be assigned to a flight crew].

6. Andrey Yevgenevich Zaytsev was part-time backup researcher on Soyuz TM-5 in 1988, apparently standing in for Serebrov for the first few months of training before Serebrov returned to flight status by the time of the actual mission. He was born August 5, 1957 in Tula. He is a Russian and a party member. He graduated from the Bauman school (Moscow Higher Technical University, or MVTU) in 1980 and has been in the cosmonaut corps since February 1987. [As with Kaleri, the presence of such an inexperienced cosmonaut on a backup team shows a very low level of better trained cosmonauts.]

7. Aleksandr Vladimirovich Shchukin was the backup researcher (shuttle pilot) on Soyuz TM-4 in December 1987. He was born January 19, 1946, in Vienna, Austria, where his family was in military service. He is a Belorussian and a party member. He graduated from Kachinskiy Higher Aviation Pilots School in 1970, and from Moscow Aviation Institute in 1980. He has been in the cosmonaut corps since February 1982.

The release of this information is in keeping with recent advances in space history openness. We should all applaud the Soviet officials who are implementing the policy of 'glasnost', and we should use the opportunity to extract as much new information as possible for as long as the present policy lasts.

JAMES OBERG
Dickinson, Texas, USA

* [....] denotes writer's own comments.

Nuclear Propulsion in the USSR

Sir, It is apparent that the USSR has undertaken both active work and theoretical studies in examining the possibilities of nuclear propulsion. Evidence for this appears in a recently-published book, "Manufacturing in Space: Processing Problems and Advances" (Moscow, 1985) edited by V.S. Avdeuyevsky, who refers on p.235 to "A large amount of research and development work on nuclear rockets... (though) they remain far from mission status".

Vyacheslav Balebanov, Deputy Director of Space Research, in discussing a manned mission to Mars earlier this year also mentioned the possibility adding:

> "A nuclear-propelled journey would require the assembly in low-Earth orbit of a single craft, weighing 1,190 tonnes, using ten Energia missions. Five nuclear motors with a thrust of 104 tonnes would be used, one of which would be required for the return journey. A rocket-propelled journey would take 450 days, using a craft weighing between 930 and 1,240 tonnes, assembled by five to seven Energias" [1].

Nuclear propulsion studies were conducted in the US in the 1960's and early 1970's, possibly then with more intensity, but no such programme exists today.

P. PESAVENTO
Philadelphia, USA

Reference

1 Flight International, March 26 1988, p 18

CORRESPONDENCE

Space Station Transportation

Sir, The recent decision by NASA to study the use of expendable launch vehicles for resupply missions to the space station Freedom is to commended. Although one of the main objectives of the space shuttle was to facilitate the construction of a large permanently manned space station at some point, operational experience, along with the Challenger disaster, has shown the limitations of the current shuttle design. Some of the burden can be removed from the shuttle fleet by employing unmanned launch vehicles for routine resupply missions, thus ensuring that the orbiters can achieve at least the minimum flight rate required for crew replacement and station servicing.

In similar vein, one would hope that NASA will proceed with the development of a separate station-based return capsule, rather than the proposed concept of a ground-based shuttle as the means of achieving an assured crew return capability. The development of a Crew Emergency Rescue Vehicle, even if it is little more than an updated Apollo command module, would give Freedom's crew an improved chance of survival in the event of a sudden station-related malfunction.

J.R. ROBINSON
Oxford, UK

Weightlessness in Space

Sir, I read with interest Curtis Peebles' article 'Flying the Weightless Profile' (***Spaceflight***, May 1988, p.248). I wondered if I would be permitted to clarify a point of basic physics. The author states that: "A crewman of an orbiting spacecraft is weightless due to a balancing act between the centrifugal force due to the orbital velocity and the gravitational pull of the Earth." This is incorrect as the centrifugal force as described *does not exist*.

A satellite stays in orbit because it experiences a sufficient force toward the centre of the its parent body. The force required to keep a satellite 'continually falling' (as Newton first explained) is called a centripetal force and this can be shown to depend on the mass of the satellite, its orbital velocity and the radius of the orbit measured from the centre of the planet. It is gravity that provides the required centripetal force.

Why then are the astronauts 'weightless'? This is actually a misnomer. All objects fall with the same acceleration in a gravitational field. On Apollo 15 Dave Scott gave a classic demonstration of this discovery of Galileo. He dropped a hammer and a feather simultaneously and they hit the ground together (on the Moon there is no air resistance to confuse the issue). Thus, the astronauts in a spacecraft have the same centripetal acceleration as their spacecraft. There is no reaction between the astronauts and their spacecraft and so *relative to the spacecraft* they seem 'weightless'.

JOHN DUNTHORNE

Head of Craft, Design & Technology
King Edward VI School, Louth, UK

Curtis Peebles replies: John Dunthorne is of course correct – "Centrifugal Force" is at best a non-rigorous approximation. Unfortunately, words do not have the precision of physics. The terms "Zero Gravity" and "Free Fall" are often used. (Note the "Zero 'G'fects" patch on Byron Lichtenberg's flight suit). Yet from a strict viewpoint, they give the wrong impression. The first implies the spacecraft has escaped completely the influence of gravity, the other implies the "feeling" of falling.

Metric or Imperial Space Stations?

Sir, It has been announced that the International Space Station is to use the imperial unit system instead of the metric system. I have been waiting for readers to respond to this, but I have not seen any response within the pages of ***Spaceflight***. I take the view that this is a serious mistake by NASA and the decision will cause more trouble than it is worth.

The reason that NASA chose the imperial system is primarily due to safety. They reason that in an emergency, an astronaut under stress may confuse a metric unit for an imperial unit (for example gallons instead of litres). However, I think that the astronauts are highly trained and motivated and are not likely to make such a mistake. Most astronauts have science or engineering degrees where the metric system is primarily used (especially for science) and should already be quite familiar with using it. They spend much time in simulators, preparing for emergencies. I am sure that in simulations that the simulation controllers will do their very best to try and catch off guard any astronaut who confuses the two systems. Also, did not the Apollo programme (with a much more dangerous mission) use metric units (as well as some imperial units)?

The above explains why I think the reason for choosing the imperial system is weak. However, there is a much more fundamental reason behind using the metric system.

The metric system is international and is used by nearly every country except the US (and it is supposed to be an International Space Station). What about future collaboration with other countries? The choice of the imperial system will now mean that the imperial system will be used on much larger projects, such as a Moon base or Mars landing. Will the US really expect cooperation with other countries (such as the USSR) if it expects them to also use the imperial system? I expect not, and the US will have to revert back to the metric system if it is to be a part of future large programmes beyond the Space Station.

For the present I have yet to find out how this decision affects the other partners of the Space Station. Do the Europeans and Japanese now have to speak imperial when on the station? Do all the parts of the non-US modules have to be made using imperial dimensions? From this decision it appears that NASA is moving backwards. I only hope that NASA reverses its ruling for the good of future space exploration.

STEVEN PIETROBON
Indiana, USA

Booster Explanation

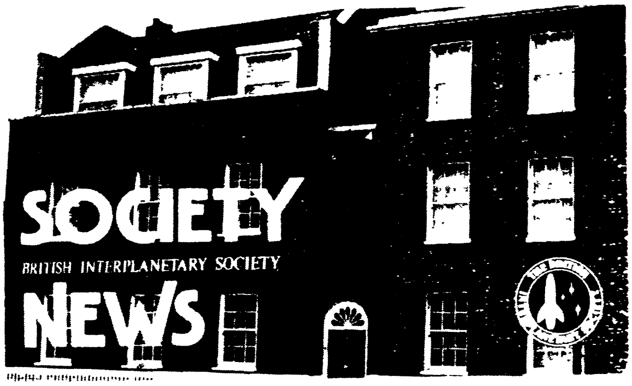
Sir, With regard to Mr. Smye-Rumsby's letter (***Spaceflight***, August 1988) and although I am not an engineer, I think I can provide an explanation to the question of the continued flight of Challenger's SRBs after the explosion.

When the external tank exploded, this severed all connection to the orbiter's three main engines, therefore bringing their thrust to a sudden end. At the same time, the SRBs were detached, removing their component of the system's thrust. The resulting deceleration, coupled with the likely rotation of Challenger about one or more of its axes, and the attendant aerodynamic pressures would cause the orbiter to break up.

However, the SRBs as noted on many occasions, cannot be shut down once ignited. They therefore continued to fire, and when their attachment points to the external tank were severed they were able to fly free of the fireball at a high enough velocity to prevent their own immediate destruction.

The SRBs continued to fly until the Range Safety Officer ordered their destruction. This is the only such intervention ever made in a manned US space flight, and it did not involve the manned section of the shuttle stack.

GRAHAM AUTY
Leeds, Yorkshire



Communication Speed Up

The Society has now added a Fax to its equipment to speed-up its communications with members and contributors.

Our new Fax Number is **01-820 1504.**

Renovation work being carried out at our HQ premises has also been extended to include a complete new modern telephone installation to help speed up both internal and external calls.

Library News

The Library is closed until further notice owing to continuing rebuilding and construction work on the Society's premises. An announcement about reopening will appear as soon as all this is behind us. In the interim, members wishing to return Library books to HQ may do so at any time during normal office hours.

In spite of this upheaval, the acquisition of new technical books on astronomy and space continues apace. The Library now possesses a very high proportion of current works and pressure on shelf space is acute. This underlines the importance of plans for an extension to the Society's premises, a half of which is scheduled for Library use. Meanwhile, non-technical books are being phased out of the Library to make way for the new arrivals. Items thus withdrawn are sold to members at very reasonable prices (a list of books and reports currently for sale is available on request), with the funds raised used for Archival purposes.

Among unique items presented to the Society recently was a copy of "On The Shoulders of Titans", the frontispiece containing the signatures of twenty-eight major participants in the Gemini Programme, presented by Capt. R.F. Freitag, models of LEM and an early Goddard rocket, respectively, from Dr. Anthony R. Michaelis, and a number of volumes specifically aimed at filling gaps on our Library shelves from Lester Winick.

Our grateful thanks go to these donors and many others who have contributed in many other ways.

Supernova Coin?

The Society has acquired an interesting coin issued in Tralles, a Greek city which stood on a lofty plateau overlooking the River Meander. The coin depicts a Roman Magistrate, C. Fannius, who held office in 49-48 BC, and thus allows us to date it closely. The reverse of the coin, besides giving descriptions in Latin, gives the name of the Roman Praeter and Magistrate and shows two erect snakes on either side of a round temple with a small statue of Athena on the roof. This is where a point of great interest arises because two stars are shown by the head of the snakes, symbols which match exactly those used a thousand years later on a Byzantine coin which recorded the appearance of the Crab Supernova in 1054 AD.

The question to be asked is, does this coin also record the appearance of a supernova, this time around 48 BC? Reference to the table on page 46 of *"The Historical Supernovae"* by D.H. Clark and F.R. Stephenson (Pergamon Press, 1977) shows that a supernova did appear in May, 48 BC. The position reported by the Chinese was RA 18 40, Dec.+25 10 (epoch 1950). This was at the time of the war between Caesar and Pompey, when omens from the stars were eagerly sought, so there ought to be another Western record of the supernova. Lucanus in *"Pharsalia"* (i.529) says that, in 48 BC, but without giving the month, "A comet, that terrible star which upsets the powers of the Earth, showed its portentious head". De Mailla (iii 155) adds that a long comet was seen that April near Beta Cassiopieae, an object also referred to by Biot in March as going towards the "Blue Palace" i.e. the circle of perpetual apparition around 34 degrees latitude North.

Both of these records seem clearly to be comets which, by coincidence, appeared around the same time as the supernova, though it is not always clear to decipher from early writings which is which. In any even, a different position for the supernova was given by the Chinese, but as this was in Hercules, it should have been clearly visible to the Romans.

The coin we have appears to be the only one of its type in existence. Two other similar coins are recorded but both are without the stars.

The intriguing question remains, is there, somewhere, a Greek or Roman account which refers to Supernova in 48 BC in unmistakable terms?

We would welcome hearing from any readers able to help.

JBIS

New readers may be interested to learn that the Society's technical magazine, the *Journal of the British Interplanetary Society* (JBIS), first appeared in 1934 and has now contributed substantially to space developments over more than 50 years. Many of its issues are dedicated to particular space themes, activities or projects, and often provide a unique spectrum of the space work associated with a particular Establishment, University or Industrial group.

The contents and theme of every current issue of JBIS are listed in ***'Spaceflight'***, on publication, to enable interesting papers to be readily identified.

Members of the Society are able to subscribe to JBIS on especially favourable terms. Others who wish to secure a single issue only will find the rates for both members and non-members in the advertisement on p.375.

A recently-published volume on the late George Bernard Shaw (Collected Letters 1926-1950, Ed. Dan. H. Laurence, Max Reinhardt, 966pp, £30.00, 1988), contains an interesting reference to the Society.

It transpires that, on January 25, 1947, Arthur C. Clarke sent a copy of JBIS containing his paper "The Challenge of the Spaceship" to GBS who received it enthusiastically and joined as a Member and remained so for the rest of his life. The JBIS paper had been presented in September 1946, at about the same time as the death of Geoffrey De Havilland while testing the experimental DH 108 jet plane over the Thames which also formed part of the correspondence.

A.C. Clarke, in attempting to explain the cause of the accident, received from GBS a reply which, he says, "remains one of the most baffling communications I have ever received".

The story not recorded in the book) then transfers to our Executive Secretary who had the unenviable task of extracting the annual dues on January 1st from the GBS who, true to his contrary nature, insisted on remitting on 1st of July instead.

The matter was resolved in a manner satisfactory to both parties: GBS was inveigled, unwittingly, to make two payments one year and thus remained, thereafter, permanently in credit!

The Aerospace Museum at RAF Cosford

Dave Fearn, who was with the BIS party visiting the Aerospace Museum at RAF Cosford earlier this year, found it a goldern opportunity to examine some of the original German rocket technology that produced such a profound influence on the world's space programmes, for many of the German scientists and engineers involved were recruited after the War to work in the US and Soviet Union.

German rockets on show included the V2 (or A4) missile with two almost unique examples of its mobile erector launcher.

Germany developed an amazing variety of unguided and guided anti-aircraft and air-to-surface missiles in the early 1940's, nearly 140 types in all. They even experimented, successfully, with firing solid propellant rockets from submerged submarines. Many of these missiles were the products of test programmes carried out at Peenemunde.

A principle crucial to later endeavours is shown by a two-stage subsonic anti-aircraft missile, the Rheintochter, developed in 1942 by Rheinmetall-Borsig. The first example, the Mark RI, had two solid propellant motors, while the operational model, the RIII, had a solid take-off stage and a liquid motor for flight and interception. Control was from the ground via a radio link. Maximum altitude was about 5½ miles.

The Herschel HS-117 Schmetterling (Butterfly) was also radio controlled. It had two small solid motors for take-off and a 350 lb thrust BMW liquid-fuelled rocket for flight. Maximum altitude was again 5½ miles.

An air-to-surface radio-controlled missile, the Herschel HS-293, was developed from a standard 500 kg bomb and intended primarily for attacks on shipping. Although basically a gliding weapon, a rocket motor was added to assist armour penetration.

The V1 and HS-293 were the forerunners of the modern cruise missile. An early British example of this class of weapon is on show at the Museum. This is the Blue Steel missile. It was produced by Avro for use on the Victor and Vulcan bombers (also on display). It is 35 feet long, weighs 15,000 lb at launch and has a range of 200 miles, with a maximum altitude of 12 miles. Its motor is the 20,000 lb thrust Bristol Siddeley Stentor, using HTP/kerosene fuel. The later, but unsuccessful, US Skybolt is also on display.

Rocket-powered aircraft, much in evidence, included the amazing Me 163 Komet intercepter of WW II, which had a phenomenal climb rate of 33,000 feet in only two minutes 40 seconds after engine start. The motor was the Walter HWK 109-509A-1, which produced 3750 lb thrust for a weight of only 365 lb. It burned hydrogen peroxide (T-Stoff) and hydrazine in methyl alcohol (C-Stoff).

A more modern rocket-powered interceptor, from the mid-1950's, is the superb Saunders Roe SR 53 which, but for an unfortunate political decision, might well have taken the huge market that eventually went to the Lockheed F-104 Starfighter. The SR 53 was powered by an AS Viper turbojet and a DH Spectre rocket motor. The surviving prototype, XD145, is displayed.

Opportunities lost through adverse political decisions are illustrated elsewhere in the collection, for example an outstanding exhibit is the second prototype, XR220, of the BAC TSR 2.

The only space exhibit spotted was a Skynet II spacecraft built by MSDS and Philco-Ford in the early 1970's. This generation of UK military communications satellites suffered one launch failure before Skynet II B was placed successfully in orbit on 22 November 1974 by a Thor Delta 2313.

A single afternoon for such a fascinating visit was too short to do the exhibition justice. Apart from over 60 aircraft on display soon to be augmented further, the collection of German rockets added a special bonus for space enthusiasts.

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Subject to space being available members may also apply for a ticket for one guest.

30 Sept – 2 October 1988 **Conference**

SPACE '88

Major weekend space conference, including varied programme of lectures and full social programme.

Venue: White Rock Theatre, Hastings, Sussex, UK

Registration
Forms and detailed programme are available from the Society by sending 20p stamp or international reply coupon.

8-15 October 1988 **Congress**

39th IAF CONGRESS

Venue: Bangalore, India.

Registration
Details can be obtained from the Executive Secretary

2 November 1988, 7-8.30 p.m. **Lecture**

UK INVOLVEMENT IN SATELLITE NAVIGATION

Dr. I.L. Jones (*British National Space Centre*)

Members and their guests only. Please apply for admission tickets in good time enclosing SAE.

15 November 1988, 10-4.30 p.m. **Symposium**

EXTENDING THE SPACE INFRASTRUCTURE

The reports of the National Commission on Space and Dr. Sally Ride have paved the way for a new innovative space policy in the United States. It encompasses the setting up of bases on the Moon and manned exploration of the planet Mars. The purpose of the symposium is to encourage and review American proposals and possible European contributions.

The symposium covers the following subjects:
- Infrastructure planning
- Orbital transfer systems
- Geostationary operations
- Lunar transportation system
- Lunar bases
- Planetary exploration systems
- Exploitation of the solar system.

Offers of Papers are invited
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms and other details are available from the Society. Please enclose SAE.

30 November 1988, 6.30-8.30 p.m. **Visit**

SCIENCE MUSEUM

A special visit of Society members to the Science Museum in South Kensington. The programme will provide an opportunity for a leisurely view of the Space Gallery and to see vintage space film footage.

The fee will be £6.00 per member to cover the cost of a buffet with wine which will be provided.

Advanced registration is necessary as the party will be limited in number. Guests will be allowed if space is available. Forms are available from the Executive Secretary

BOOK NOTICES

The Space-Age Solar System

Joseph F. Baugher, John Wiley & Sons Ltd., Baffins Lane, Chichester, W. Sussex PO19 1UD. 1988, 425pp, £28.65.

Our knowledge of astronomy nowadays is constantly in the melting pot: no other scientific discipline has a body of knowledge which is so constantly changing. Each year, new discoveries supplant old assumptions, sometimes forcing a re-think of astronomy's very foundations. Even our own solar system, our own "celestial neighbourhood", is seen as a far different place from concepts only five years ago.

This book provides an up-to-date guide to the latest facts, findings and discoveries about the Sun, Moon and Planets, beginning from the centre out and moving via the rocky inner planets towards the gaint distant icy worlds in its outer reaches and incorporating, en route, such matters as the probes to Halley's Comet and the Voyager Fly-By of Uranus, ending with comment on a suspected, but as yet undiscovered, tenth planet.

A number of appendices add to the wealth of ready-to-hand basic data.

Nearby Galaxies Catalogue

R. Brent Tully, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England, 1988, 214pp. £30.00.

This compendium provides a companion to the Nearby Galaxies Atlas (reviewed in ***Spaceflight***, February 1988, p.88) and contains data on 2,367 galaxies with velocities of less than 3000 km/second.

The Catalogue is divided into three parts. The first and by far the largest provides known information about each of the galaxies listed, all in tabular form with data listed under 18 headings, one element being group affiliation. The second is a similar listing but rearranged in different order to classify nearby galaxies by group affiliation. This specifies the memberships of 36 clouds, 254 associations and 336 groups having two or more members; the remaining 31 galaxies cannot be identified with any of these.

Finally, a very short section identifies those rich clusters of galaxies which delineate the supercluster complexes shown on the last two plates of the Atlas.

Communications Services via Satellite

G.E. Lewis, Blackwell Scientific Publications Ltd., Osney Mead, Oxford, OX2 0EL, England, 1988, 308pp. £45.00.

Satellites introduced a new concept of signals delivery into telecommunications for they are able to carry not only all the existing services – often including previously inaccessible areas – but have also made possible a new range of services not previously feasible.

Satellite communications systems, however, provide their own series of new technical problems for those engineers involved in communications and TV service equipment. The systems design engineer must know how to assemble a cost-effective and efficient system from the various standard units available and advanced students, too, must be aware of similar concepts.

This book is directed towards such engineers and others who need an invaluable guide as to how a system signal is coded, modulated, demodulated and processed and, from it, obtain a good understanding of the way in which such systems function. In fact, several systems are described and a number of analyses and design rules set out.

It includes five chapters of communications principles which explain how and why certain system parameters are important. Many actual systems are covered, the approach being largely based on systems/block diagrams, though the design and construction of communications satellites and their methods of launch have been purposely omitted, as these are well documented elsewhere.

The book can be used either as an aid for self-training by practising engineers or by way of background to students following more formalised programmes.

Astrophysics of the Sun

H. Zirin. Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 1988. 433pp. £37.50.

This is an entirely new edition of a classic text on the solar atmosphere. The treatment, which emphasises physical rather than mathematical aspects, combines an introductory course in astrophysics with a comprehensive description of the theoretical and observational positions. A special feature is the inclusion of a large number of spectacular new solar photographs, including many of the best from the world's observatories.

Many improvements have been made to the previous edition in 1966 e.g. the second half of the book has been completely rewritten to reflect 20 years of further progress. Although much basic physical theory is unchanged and great progress made through the opening of ultra-violet, X-ray and microwave regions to observation, it may be of some surprise to learn that, until recently, the extent of observational knowledge of the Sun was quite limited. Even now, not all areas are being exploited fully. for example, the study of solar granules, sunspots and prominences – once major fields of astronomical interest – seen now to be regarded as of diminishing importance.

1988 European Space Directory

Sevig Press, 5 Rue Alexandre Cabanel, F-75015 Paris, France, 1988, 527pp, French Francs 725 (plus 25FF mailing costs).

This new Directory, sponsored by Eurospace, is the third edition of a reference work which grows from strength to strength. The information provided this year has not been a simple update but has been expanded considerably by the introduction of much new material, including a comprehensive coverage of the Canadian Space Industry.

Besides the directory proper, there is a substantial portion of editorial text describing European space programmes, budgets and infrastructure, together with a detailed run-down of communications, meteorological and remote sensing satellites. An analysis of the contracts awarded by ESA to industry during the periods 1972-82 and 1983-87 provide both European and national perspectives on ESA involvement with its industrial partners. ESA budgets and programmes for 1972-87 are listed by country with a detailed list of European space projects for the decade 1988-1998 provided.

Text on 361 individual space organisations is both precise and clear and contains a wealth of information not only about the organisation itself but includes data on 1600 key personnel, turnover, structure and activities, main specialisations and current contracts. There is also a short but useful "Who's Who".

Supernova 1987A in the Large Magellanic Cloud

M. Kafatos & A. Michalitsianos, Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge, CB2 2RU, England, 1988, 486pp, £35.00.

The appearance of Supernova 1987A in the Large Magellanic Cloud represented the brightest Supernova explosion since the invention of the telescope and the first naked-eye Supernova to be seen since the time of Kepler, in 1572. Unfortunately, the Supernova was visible only in Southern skies where, for a time, it was rivalled by the appearance of Halley's Comet close-by.

This book collects together 70 papers presented in October 1987 which provide a fascinating summary of the status of observations of the Supernova up to six months after the outburst. Not only do they give a comprehensive review of the major observational and theoretical results to that time but provide a considerable store of new information. One of the unprecedented attributes of Supernova 1987A was that it provided the first occasion when direct observational evidence became available about the progenitor star. Examination of pre-outburst plates revealed an excellent positional coincidence between the supernova and a 12th magnitude star, with the presence of two further stars indicating an apparent multiple system.

Other highlights include such matters as results from the three major neutrino experiments involved in the detection of the neutrino burst: optical, infrared and radio observations: ultraviolet spectroscopy from the IUE satellite and the detection of hard and soft X-ray emission from an experiment on-board the Soviet Mir Space Station

Many of the theoretical papers are addressed to the physics behind the nature of the outburst and core collapse, models of the emission from the ejected shell and the interaction of ejecta with the interstellar environment.

The Atmosphere of the Sun

C.J. Durrant, Adam Hilger, Techno House, Redcliffe Way, Bristol BS1 6NX. 1988. 168pp. £23.50.

The familiar Sun is one of the most fascinating objects in the sky, presenting ever-changing surface patterns as a result of deep fundamental physical processes.

The starting point for everything which happens in the Sun's atmosphere is fixed by the dramatic processes which take place within its interior. Nuclear transformations produce radiation, convection creates motion and a dynamo effect produces magnetism. Different regions of the atmosphere are dominated by different combinations of energy sources. For example, cell interiors in the chromosphere result from mechanical-radiative processes, while mechanical-magnetic processes dominate the cell boundaries.

A further chapter devoted to solar surface activity includes the solar sunspot cycle and the eruptive phenomena such as flares and prominences.

An Appendix contains a straightforward account of plasmas and radiation, both essential for gaining a fundamental understanding of the Sun.

History of Oriental Astronomy

G. Swarup *et al.* Cambridge University Press, The Edinburgh Building, Shaftesbury Road, Cambridge CB2 2RU. 1987. 285pp, £27.50.

Any discussion of the achievements and characteristics of oriental astronomy during the ancient and medieval periods is always of interest. This one describes both the regional development of and mutual influence on each other of Babylonian, Greek, Indian, Chinese, Arabic and European astronomy, dating from about 3000 BC to recent times.

Most of the topics are reviewed critically e.g. in discussing not only ancient and medieval astronomical observatories and their instruments but also ancient records relating to eclipses, supernovae and comets.

The result illustrates the development of astronomy from the earliest attempts at time-determination to the endeavour to predict the positions and conjunction of heavenly bodies, a matter which led eventually to the development of algebra and trigonometry and which revolutionised astronomical planetary models.

The interplay between social needs, new observations and the growth of theory illuminates some of the fascinating yet the most fundamental problems relating to the growth of, probably, the oldest science in the world, in a number of widely disparate cultures.

Fluid Sciences and Materials Science in Space

H U. Walter, Springer-Verlag GmbH & Co., Postfach 105160, Haberstrasse 7, D-6900 Heidelberg 1, Germany, 1987, 745pp. DM 320.

Almost fifty European scientists have cooperated in the preparation of this book, a synergetic approach which has greatly enhanced the depth and scope of the contributions as a whole. Every chapter begins by describing the theoretical background to each microgravity experiment, followed by a review of the actual experiment undertaken and a critical discussion of the results obtained.

Contributions fall under the general headings of fluid sciences, physical chemistry and materials science, the latter including crystal growth, alloys, composites and glasses. The volume ends with an analysis of the limitations of microgravity and its applications, including reference to future industrial potential.

It thus provides a complete review of the present status of microgravity research up to the results of the D-1 Spacelab missions. The Challenger disaster which followed shortly afterwards resulted in a serious discontinuity of flight opportunities though the forthcoming space station will undoubtedly provide ample opportunities in the longer term. Meanwhile, parabolic aircraft flights, sounding rockets and work on the delayed shuttle-dependent missions (Spacelab D-2, the IML Missions and Eureca 1) have kept experimenters reasonably busy in the meantime.

The volume demonstrates that this is a new branch of experimental physics which clearly merits the attention of the scientific community at large. The potential scientific and technological benefits are substantial and commercial endeavours may well subsequently become viable though these will need to be evaluated in a hard-headed manner.

Materials are of paramount importance in high-technology systems and a key element in ensuring the competiveness of industrial nations. It follows, therefore, that it is not only mandatory for Europe to find its place in this field but to follow a consistent policy to realise its most valuable potential.

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Spaceflight

The International Magazine of Space and Astronautics

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Front Cover: A dramatic artist's impression of Shuttle-C. The next step for the shuttle programme? A full report appears on p.412.

SHUTTLE—The Next Steps

The Shuttle, though a remarkable technological achievement, never achieved its intended payload capacity and recent safety modifications have further degraded its performance by approximately 4,800 pounds. Advanced Solid Rocket Motors (ASRMs) or Liquid Rocket Boosters (LRBs) have the potential to restore some of this performance. Studies on both are underway. Other possible options include manufacturing the Shuttle External Tank (ET) out of lighter materials, and improving ground processing to increase the Shuttle's launch rate.

*This special **Spaceflight** report was compiled from the very latest information supplied to the Congress of the United States by the Office of Technology Assessment.*

Advanced Solid Rocket Motors (ASRMs)

The ASRM programme aims to improve Shuttle safety and performance significantly by:

- designing the field joints to close rather than open when pressurised,
- reducing the number of factory joints and the number of parts,
- designing the ASRMs so that the Space Shuttle Main Engines no longer need to be throttled during the region of maximum dynamic pressure,
- replacing asbestos-bearing materials,
- incorporating process controls and automation to eliminate labour intensive operations and improve motor quality, reproducibility, and safety.

An example of the savings potential offered by improved process control is the new, automated, manufacturing facility for the Titan IV solid rocket motors operated by the Hercules Aerospace Company. Compared to an older United Technologies facility where the workforce was around 35, Hercules can cast four times the propellant at a time with one-tenth the personnel.

ASRMs would add an estimated 12,000 pounds of lift to the Shuttle, allowing it to lift 61,000 pounds to a 150 nm orbit. At the proposed Space Station orbit (220 nm), ASRMs could allow a Shuttle to lift 58,000 pounds instead of 46,000 pounds, significantly aiding Space Station deployment. The first phase of Space Station deployment is presently scheduled to take about three years and 19 Shuttle flights. With ASRMs this could be accomplished with five fewer flights in four fewer months. Furthermore, if even more capability were desired, NASA could decide to develop LRBs and ASRMs capable of lifting 15,000 rather than 12,000 additional pounds.

NASA believes that ASRMs would require about 5 years and $1 to $1.5 billion for design, development, test and evaluation. A set of ASRMs could cost $40 to $50 million, or slightly more than the cost of present Solid Rocket Boosters.

In late August NASA issued a request for proposals inviting industry to compete for the design, development, test and evaluation of an ASRM.

The request for proposals asks interested firms to propose how they would design, build and test the ASRM and the necessary production and testing facilities.

On July 26, the agency announced its selection of the government-owned sites to be available as locations for the new rocket motor production and test facilities. The Tennessee Valley Authority property known as Yellow Creek, in Mississippi, is the government site selected for the production facility, and NASA's Stennis Space Center near Bay St. Louis, Mississippi, is the site selected for the test facility.

Firms which respond to the request for proposals will use the Yellow Creek and Stennis locations as a common basis for proposing government-owned, contractor-operated facilities.

Companies also will be encouraged to make use of available manufacturing, space and computing capabilities at NASA's Michoud Assembly Facility and Slidell Computer Complex, both located in southeastern Louisiana.

In addition, the request for proposals permits an optional proposal under specified conditions for a privately-owned rocket facility to be located on a site of the company's choice.

Firms will have 60 days to prepare and submit their proposals, the contract is expected to be awarded in early 1989.

The overall cost of the design, development, test and evaluation effort is estimated at just under $1 billion, including modern tooling and equipment and the supporting governmental effort. An additional cost of $200-$300 million is anticipated for construction of the facilities. In addition to the basic design and development, the contract also will include delivery of rocket motors for six Shuttle missions.

The design, development, test and evaluation contract will be for an approximate 5-year effort leading to delivery of the first flight set by 1994 and a flight verification program of six Shuttle missions. Plans call for full phase-in of the new motor over an approximate 3-year period.

Liquid Rocket Boosters (LRBs)

In parallel with the ASRM studies, NASA is studying ways to enhance the Shuttle's performance by replacing the SRBs with LRBs. Like ASRMs, LRBs could be designed to provide an additional 12,000 pounds of lift over present SRBs. In September 1987 General Dynamics and Martin Marietta began LRB conceptual design studies. The analysis will consider performance, safety, reliability, costs, environmental impact, and ease of integration with the Shuttle and launch facilities. In the early 1970s NASA compared solid and liquid booster technology for use on the Shuttle. NASA chose solids because it estimated that the liquid booster would cost from $0.5 to 1.0 billion more to develop than a solid rocket motor.

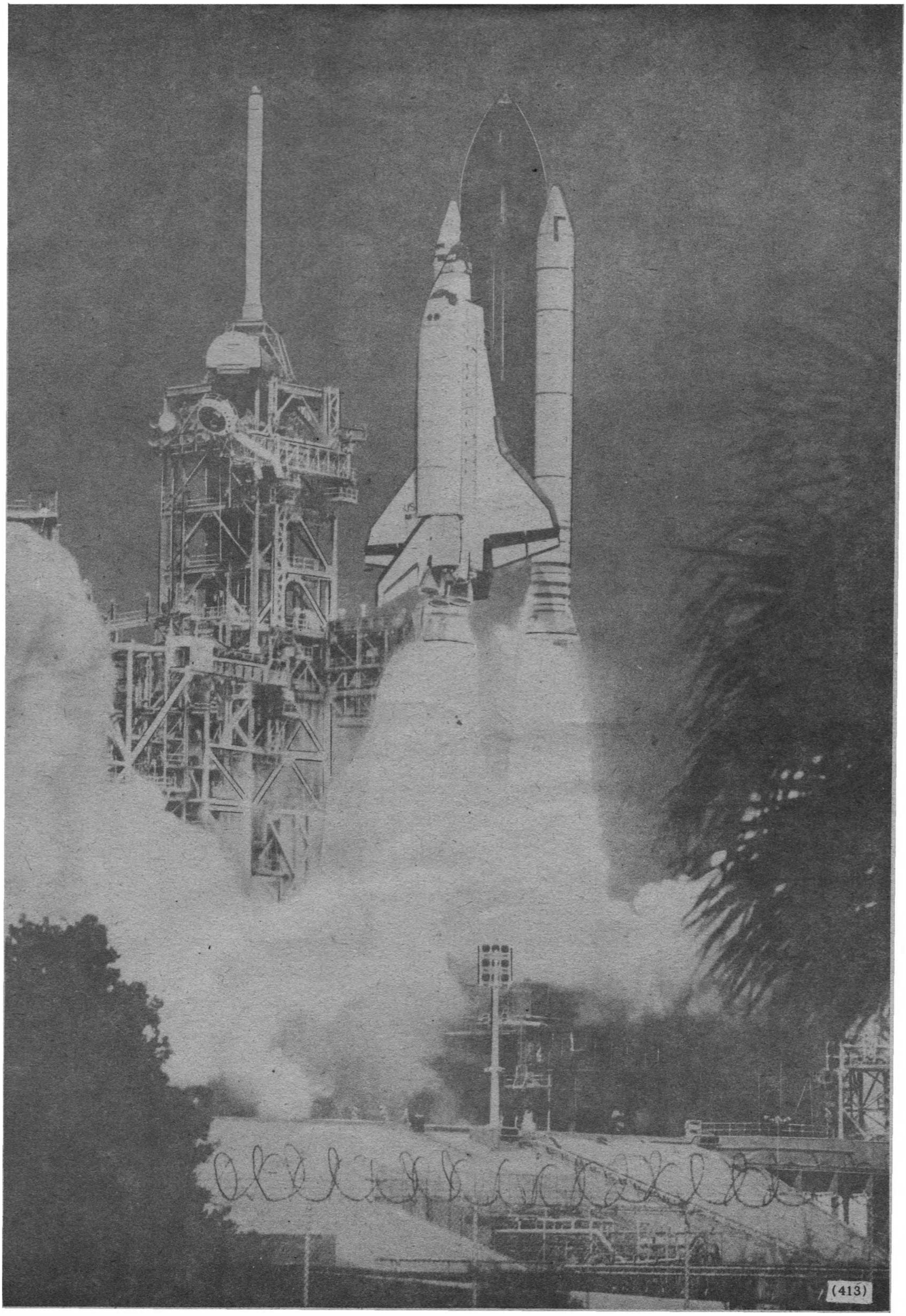
LRBs should have several advantages over SRBs. A flight-ready set of LRBs could be test-fired before they were actually used on a mission. LRBs might also improve the range of launch abort options for the Shuttle, compared with existing SRBs or ASRMs. LRBs can be instrumented and computerised to detect imminent failure and to select the safest available course of action. Unlike solid boosters, that burn their fuel until spent once ignited, LRBs could be shut down or throttled up if necessary to abort a launch safely. Launch operators could also change the thrust profiles of LRBs as mission requirements dictated, while SRB segments follow a specific thrust profile once cast. One-piece LRBs should have shorter processing times than segmented SRBs, which needed about 21 days for stacking before the Challenger accident, and around 70 days for the first post-Challenger flight. LRBs might provide a more benign payload environment than SRBs as a result of their more gradual start and lower acoustic levels. These factors may also extend the orbiter's lifetimes by reducing structural stress induced by lift-off noise and vibration. LRBs would also produce less environmentally contaminating exhaust products than current SRBs and would eliminate operations involving hazardous propellants in the Vehicle Assembly Building. Finally, LRBs could have applications beyond just the Space Shuttle, including Shuttle-C, an Advanced Launch System, or even as a new stand alone booster with a 50,000 to 80,000 pound lift capacity.

LRBs are a long-term option and are unlikely to be available until the turn of the century.

Lighter Tanks

Another way to increase the Shuttle's capability would be to make the Shuttle's External Tank out of a new alloy, such as aluminium-lithium,

The Space Shuttle Discovery blasts off from the Pad 39B at the Kennedy Space Center, on September 29, proving the Shuttle programme is back on course. But the shuttle will never achieve its intended goals, in this article we take a look at possible improvements to the vehicle. ***NASA***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instead of aluminium. Aluminium-lithium offers a 20 to 30 per cent weight saving compared to the aluminium alloy now used in the External Tank. If the External Tanks were made of aluminum-lithium and the inter-tanks were made of graphite epoxy, the Shuttle would weigh 12,000 pounds less at lift-off. Since the External Tank is carried nearly all the way to orbit, reducing the weight of the External Tank by 12,000 pounds would translate into almost 12,000 pounds of increased payload capability.

Improving Shuttle Ground Operations

Introducing a number of new technologies and management strategies into Shuttle ground operations could make these operations more efficient, faster, and cheaper.

For example, introducing computerised management information systems into launch and mission control facilities could sharply reduce the amount of human effort in making, distributing, and handling paper schedules and information. It could also reduce errors and speed up sign-off procedures.

Another strategy thought to have the potential to decrease Shuttle processing time is developing "mission reconfigurable software" to accommodate rapid, high quality mission-to-mission software changes. Software writing and rewriting is presently a constraint on the Shuttle's turn-around time and consequently, its flight rate.

Shuttle-C

NASA's SPACE CARGO CARRIER

NASA envisages Shuttle-C as a reliable, unpiloted, cargo vehicle with a 100,000 to 150,000 pound payload capability to a 220 nm, 28.5 degree inclination orbit. It would use the External Tank (expendable) and Solid Rocket Boosters (reuseable) of the current Shuttle, but replace the Orbiter with an expendable cargo carrier. The cargo carrier would consist of a payload shroud, two or three Space Shuttle Main Engines (SSMEs), and a portion of the Orbital Manoeuvring System, the Shuttle's on-orbit manoeuvring thrusters.

NASA believes that the evolutionary nature of Shuttle-C would allow it to be developed in about four years. The major milestones include tests of cargo carrier structural loads, cargo carrier separation, vibro-acoustics, and propulsion tests. Some observers feel that using Shuttle-C in the vicinity of the Space Station would require developing an automatic docking system in addition to the unpiloted cargo vehicle. However, NASA's current plans are to use the Orbital Manoeuvring Vehicle (OMV) presently under development for Space Station rendezvous and proximity operations.

NASA expects Shuttle-C's reliability to be comparable to that of the Shuttle because both vehicles would employ common components. NASA sees Shuttle-C's commonality with the Shuttle as a benefit, because it would allow Shuttle-C to profit from the Shuttle's "learning curve" and avoid the "infant mortality" problems and schedule slippages normally associated with a new vehicle.

The Air Force, on the other hand, has expressed concern that such commonality could be a liability because it "places all our eggs in one basket". For example, if an SSME failed and required the grounding of the Shuttle fleet, Shuttle-C would be grounded as well because it would employ the same engines. Similarly, a major accident in launch processing could ground both vehicles.

The current Shuttle-C design would place 100,000 pounds in an equatorial LEO orbit (220 nm, 28.5 degrees), 94,000 pounds in a polar LEO orbit (160 nm), or 20,000 pounds in GEO using an existing upper stage. In addition to applications generic to all heavy lift vehicles, such as launching large space science payloads, polar platforms, Shuttle-C could also serve as a test-bed for flying new Space Shuttle elements such as ASRMs, LRBs, or variants of the SSME without risking lives or a reusable orbiter. Because the Shuttle-C could carry the Centaur upper stage, it would provide alternative access to space for heavy planetary payloads, or certain national security payloads, which currently can only fly on the Titan IV.

Perhaps Shuttle-C's strongest selling point is its contribution to deployment of the Space Station. Use of Shuttle-C could reduce the time required to deploy the Space Station from 36 months to 19 months by carrying more payload per flight. It would allow compression of nineteen Shuttle flights into seven Shuttle flights plus five Shuttle-C flights. Using Shuttle-C to deploy the Space Station could also increase the amount of equipment that could be integrated into the modules and checked out on the ground, increasing both reliability of the Space Station modules, and safety of the Shuttle crews assigned to space station assembly.

A fully instrumented Space Station lab module weighs about 69,300 pounds. Launching it on the Shuttle would require off-loading 29,800 pounds of instruments and other hardware, which would be launched on additional Shuttle flights, installed, and integrated on-orbit. Shuttle-C could launch the entire 69,300 pound lab module on one flight, reducing on-orbit assembly requirements, and possibly improving the reliability of the components. Furthermore, Shuttle-C's projected 100,000 pounds of payload capacity to Space Station orbit would satisfy about 55 per cent of the Station's annual resupply requirements in one flight.

NASA plans to use Shuttle-C only two or three times per year, a rate limited by the availability of the SSMEs it would use. To keep development costs down, NASA plans to use SSMEs after they have flown on the Shuttle. SSMEs are qualified for 20 Shuttle flights but NASA plans to use them at most 10 times. These SSMEs would then be fully inspected, refurbished, flown, and expended on the Shuttle-C. To increase Shuttle-C's flight rate beyond a few flights a year, additional SSMEs would have to be procured. This would substantially increase Shuttle-C's cost, although larger SSME production runs should produce some unit cost reduction from the present cost of $40 million per engine.

The Shuttle-C would also have a limited flight rate because, unless additional Shuttle processing facilities were constructed, it would have to be merged into the Space Shuttle processing flow. NASA estimates that Kennedy Space Center facilities would have to be modified at a cost of $20-50 million to support a combined annual Shuttle/Shuttle-C flight rate of 14 (e.g. 11 Shuttles and 3 Shuttle-Cs) without unduly disrupting Space Shuttle processing. If the combined Shuttle/Shuttle-C annual flight rates approached 20, an additional Mobile Launch Platform and an SRB Stacking Facility would be needed.

NASA estimates that Shuttle-C launches would cost about the same as the current Shuttle, though it would carry roughly three times the payload. This is about $240 million per launch divided by 120,000 pounds, or about $2,000 per pound.

NASA estimates of Shuttle-C development costs range from $740 million to $1.5 billion, excluding the costs of facility modifications. If this estimate is correct, Shuttle-C would pay for itself after being used for Space Station deployment alone. Station deployment using Shuttle-C would require seven fewer launches at a cost of $240 million each for a saving of $1.7 billion.

Cost analysis shows Shuttle-C to be uneconomical as the US's principal heavy lift launcher if there is a substantial long-term demand for such capability. However, it may be an attractive option for launching the Space Station deployment or a few large science or national security spacecraft.


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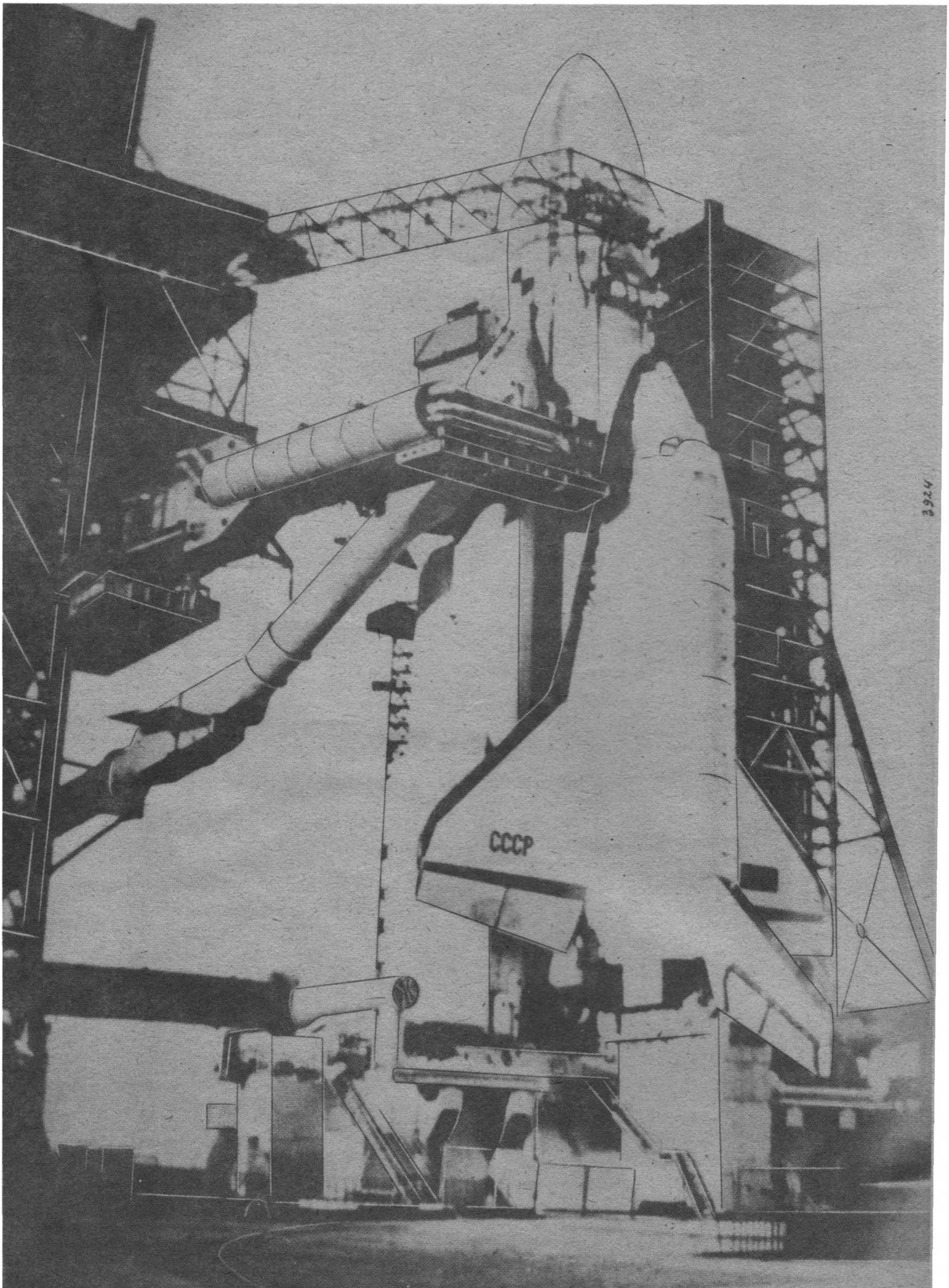

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Soviet Shuttle Launch Imminent

The launch of the Soviet Shuttle is imminent, just hours after the successful launch of Discovery the TASS Press Agency released a photograph of the shuttle attached to its Energia booster. Recently the media in the USSR has increased its coverage on the shuttle.

On October 4, Aleksandr Dunayev the head of Glavkosmos said a reusable spacecraft is to be launched by the Energia booster before the end of the year. But the launch will take place "Only after most thorough checkups and test runs on Earth." On September 26 Radio Moscow announced "Today the Soviet shuttle undergoes the last test." The Soviets will want to launch the shuttle before the bitter Soviet winter closes in, so a launch can be expected at any time.

A *Pravda* correspondent was taken for a test flight in the Soviet shuttle simulater, he revealed the name of the shuttle, VKK (Vozdushno-Kosmicheskiy Korabl). He went on to say, like the American version, the shuttle is a glider and has just one attempt at a safe touchdown, landing speed is 400km per hour.

The shuttle has ceramic tiles for protection against the heat of reentry. The *Pravda* correspondent was able to touch the tiles, "To my surprise the tiles were soft – you can scratch pieces off with your fingernail," he wrote. The shuttle was tested in a purpose built wind tunnel with a specially driven nozzle which drives a stream of hot air at speeds of up to mach 20.

Western experts were not surprised the Soviet shuttle bears a startling resemblance to the US version, they believe the USSR has avoided huge development costs by examining the design of the US shuttle. Chief Cosmonaut Vladimir Shatalov has another reason for the similarity:

"We are faced with similar problems in space which pose certain requirements in terms of the shape, mass and design of the spacecraft and their elements. The Soviet system will be in the same class with its American counterpart. They will look alike as much as current aircraft or automobiles. The Soviet space shuttle will carry the same payload as the American ones, of up to 29.5 tonnes. American shuttles carry crews of seven astronauts, the Soviet shuttle will carry as many, or more if need be."

Phobos-1 Dead in Space

The Soviet probe to Mars and its moon, Phobos-1 is dead in space with no way of reviving it. Hopes now rest with the probe's sister ship Phobos-2.

A flight controller at a brand new control centre, built for the mission, sent the wrong instructions to Phobos-1 shutting down its thrusters. The spacecraft's solar panels swung away from the Sun and all power was lost. Attempts to contact Phobos-1 failed, scientists knew there would be little hope, the satellite's electronics would be damaged beyond repair in the intense cold of space.

Soviet space official Dr. Roald Sagdeev described the incident as a "disastrous mistake," and he criticised those involved. "This disaster reminded me of Chernobyl. It was caused by poor discipline among mission controllers."

Mars '94 Takes Shape

Without even waiting for the outcome of the Phobos missions to Mars, preparations are already under way for the important set of Mars missions scheduled for 1994. Two spacecraft will leave Earth in October 1994, riding the Proton booster out of Baikonour cosmodrome. The spacecraft will arrive in August 1995 [1].

The design stage for Mars '94 will conclude in December 1988. There will be three major components:

- an orbiter (scientific payload 200kg)
- a rover/marsokhod (150kg)
- balloon.

The orbiter will have three objectives: the study of the surface of Mars and its atmosphere; the study of the interreaction between Mars and the interplanetary medium; and to act as a relay for the surface probes. The rover will have a range of 100km and a lifetime of one year.

The balloon, which will take off by day and land by night, will fly for ten days and is expected to cover a groundtrack of 1000km to 2000km. Although this component of the mission is to be prepared by the French

The launch vehicle 'Energia' with the Soviet shuttle attached at the Baikonur launch site where pre-flight preparations are currently underway. The scheduled flight will be without a crew and is designed to test the shuttle's automatic in-flight and landing systems.

By Brian Harvey

space agency CNES, preliminary Soviet testing of Martian aerostat designs began in the early autumn of 1988 [2].

The idea for a Mars balloon for this mission was conceived by Professor J E Blamont, CNES advisor. The French role will be to design and make the balloon; the Soviet space agency Glavkosmos will be responsible for the integration of the balloon with the rest of the payload.

The balloon will descend in the same canister as the rover. It will be deployed just as the rover hovers for its soft-landing. The balloon will take off at around 9 am local martian time as the Sun's rays warm up the envelope. It will soar to an altitude of between 5000m and 6000m. The balloon will hold a small gondola weighing 30kg of which about 8kg will be payload. The science package consists of:

- three cameras
- an infrared spectrometer
- a gamma spectrometer
- radar
- magnetometer
- weather station for the study of Mars' climatology [3].

The balloon will touch down at around 5 pm local martian time as the atmosphere cools and the envelope deflates. A strong guide-rope will anchor the gondola and the balloon to the ground. It may be possible to probe the ground at each night-time landing spot, with a view to determining the best landing area for the 1998 sample-recovery mission.

The balloon will require a high standard of manufacture, and can only be several microns thick. The thinness of the martian atmosphere means the envelope will require a density of material only a quarter of what is permissible on Earth.

The balloon will traverse a much wider range of Mars than the rovers. It is interesting that humankind's earliest aerial device – going back to 1783 – is now being employed at the cutting edge of space research in the 1990's. The USSR already has to its advantage the experience of having deployed the Vega 1 and 2 aerostats into the Venusian atmosphere in June 1985. Both craft drifted for 46 hours at 55km/hr, covering a distance of 12,000km [4].

J. Runavot is head of the CNES end of the Mars '94 project. Head of the balloon project is C. Tarrieu.

References

1 For background on the Soviet exploration of Mars, vide P S Clark "The Soviet Mars Programme" *Journal of the British Interplanetary Society* Vol 39 No 1 January 1986
2 Radio Moscow, 14 August 1988
3 Mars '94 un projet d'aerostat martien La lettre de CNES 116 8 June 1988.
4 Stanislav Ilyin "From project Vega to project Phobos Soviet Science and Technology" Novosti Press Almanack, 1987 189-197 Moscow 1988

French Mir Mission Preview

Regular Spaceflight correspondent *Neville Kidger* previews the joint Soviet/ French spaceflight due for launch later this month.

The first Soviet/French spaceflight took place in June/July 1982. Frenchman Jean Loup Cretien spent 189 hours 50 minutes and 52 seconds in Soyuz T-6 and Salyut 7 performing a variety of experiments many of which related to man's adaptation to weightlessness.

The second joint flight is due to begin on November 21, and will involve Cretien again with five Soviet cosmonauts during a 30 day mission which will involve 160 hours of working time in the Mir complex and some 500 kg of scientific equipment.

The flight, outlined between the French CNES space agency and the Soviet Glavkosmos organisation in March 1986, was ratified by both countries' leaders in July of that year and detailed in a meeting in the City of Yerevan, Armenia in October 1986. The project was christened "Aragats" after Armenia's highest summit.

Two French candidates for the flight arrived at Star Town in November 1986. They were Cretien and Michel Tognini, one of France's seven new astronaut trainees.* Cretien, named by CNES as the prime for the flight arrived with his family – a contrast to 1980 when he arrived on crutches leaving his family in France. Tognini was single but met and married a physical education instructor at Star Town, Elena Chechina

The scientific programme for the long flight of Cretien will include two main areas: human physiology and technical experiments

Medical Experiments

While the 1982 mission sought to understand the early phase of adaptation to weightlessness (studies continued during the flight of Frenchman Patrick Baudry on the US Space Shuttle 41-G flight in June 1985) the 1988 flight will seek to determine if a new state of balance in the body is actually attained during a longer mission.

For this purpose, a new type of echograph has been developed by CNES. Called As De Cours ("Ace of Hearts") the device uses ultrasound to provide images of the cardiovascular system. The new version allows study of the circulation of blood in the deep vessels – in particular the main truncus of venous return – as well as the determination of the volumes of the heart and other organs; this dynamic exploration is accompanied by regular hormonal measurements, 2-3 times per month, on blood and urine which will be chilled for return to Earth.

A device called Superpocket will study the neuro-sensoral system and the reconditioning of postural reflexes. A major innovation will be the restitution of movement of the subject's corporal segment by a stereoscopic image acquisition system called Kinesigraph.

The cosmonauts' flight control capacities over the period will be tested in the Viminal experiment which features a small handle moved according to visual stimuli. The French claim this experiment is at the "cutting edge of current techniques."

Before and after the flight a peripheral X-ray scanner will image the long bones of the cosmonauts, to help determine calcium loss, which the French see as the main limiting factor in the length of manned spaceflights.

Finally, an instrument called Circe will measure the ionised radiation using a proportional counter to simulate the response of human tissues to that radiation. Developed by the French Atomic Energy Centre the device may be installed on the French-inspired Hermes mini-spaceplane due for launch in the late 1990's atop an Ariane 5 launcher; currently both projects are being developed by the European Space Agency.

A Frenchman in Open Space

The most spectacular part of the flight will undoubtedly be the 5-hour EVA to be undertaken by Cretien and Aleksandr Volkov to deploy a new structure on Mir's exterior, making Cretien the first non-Soviet or non-American to participate in such an activity. Called ERA ("Air") it has been developed by Aerospatiale and comprises a hexagonal-shaped series of carbon-fibre tubes linked together by light alloy hinge joints. An interconnected series of 1 m-long bars form a series of triangles. It is bundled together in a 1 m-long x 0.6 m-diameter cylinder for delivery to Mir

During the EVA the bundle will be attached outside one of Mir's front docking ports When the two cosmonauts return inside it will automatically unfurl to its full 3.8 m-diameter shape in just four seconds, watched by a camera.

Tests will then be made of the rigidity of the structure to vibrations. These will be measured by microaccelerometers. After these tests are completed the structure will be cast off into its own orbit.

The French see ERA as a forerunner of much larger framework structures deployed in space to carry communications equipment – so called "antenna farms" – to supercede today's small communications satellites.

The mock-up of ERA has been tested in the Comex water tank near Marseilles by astronaut Haignere and a Comex diver and in an A-300 airplane during short periods of weightlessness.

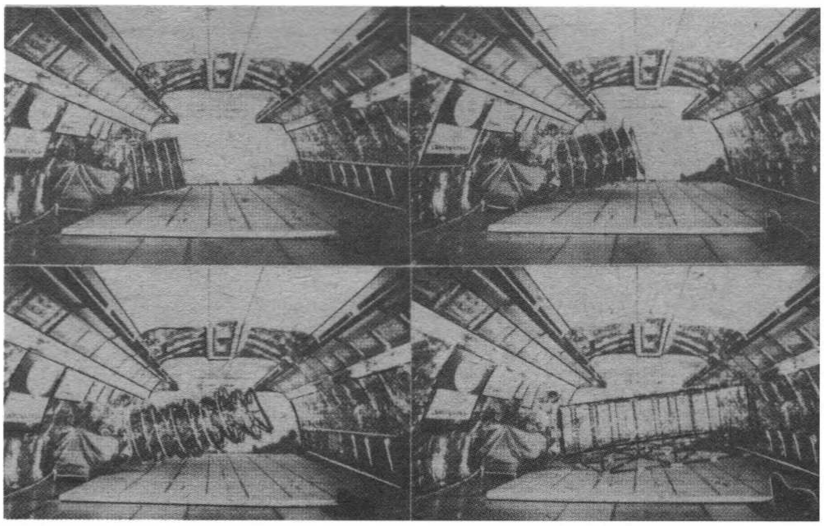
Cretien will also place on Mir's exterior a small unit with samples of materials such as paint and plastics to see how prolonged exposure, in the order of six months, to solar UV and atomic oxygen degrades them. The micrometeorite environment outside Mir will also be studied.

Two more technology experiments will be conducted inside the complex. In the first one a model of a new type of solar panel will be unfurled and stereoscopically imaged. There will be several series of tests to conduct in which the stiffness and inertia of the different segments of the panels will be assessed. In the second experiment the effects of heavy ions on a group of computer memory chips will be assessed over a six month period. The Ercos results will have applications for the electronics industry.

French officials have expressed satisfaction that only two and a half years will have passed between the identification of the experimental package to be flown and its inception in orbit. Previous experiments, such as those flown on Spacelab, have taken five years for this cycle.

Finally, in keeping with Soviet trade union restrictions, it is reported that the Soviet crews will have two days off per week. Cretien, however, is not covered by these rules and will only have one day of rest!

In this sequence of photographs the ERA structure is deployed during tests onboard an Airbus A300 during a short period of weightlessness *Aerospatiale*



* CNES candidates evaluated were Cretien, Tognini, Jean-Jaques Haiginere and Antoine Couiette CNES had named Cretien, Tognini and Jean-Francoise Clervoy as their three candidates but Clervoy was not sent to Moscow, possibly due to his association with miltary projects that were classified Couiette had actually failed to be selected as an astronaut by CNES!

Ariane Again

The launch of two communications satellites by an Ariane 3 has continued the European launcher's run of success.

Ariane V25 blasted off from the Kourou Space Centre's pad ELA 2 at 11:00 pm GMT on September 8, precisely on schedule. Atop the Ariane 3 was G-Star III and enclosed within a Sylda payload canister was SBS 5. Both satellites are American owned.

1,005 seconds after launch just before reaching the African coast the Ariane third stage placed the satellites into a Geostationary Transfer Orbit (GTO). Provisional parameters for GTO were as follows:

Apogee:	199.8km for 199.8km intended
Perigee:	36,101km for 36,205km intended
Inclination:	7 degrees for 7 degrees intended

G-Star III

The G-Star III is owned by the GTE Spacenet Corporation and is part of a system that will ultimately consist of three dual band (C and Ku-Band) Spacenet satellites and four all Ku-Band G-Star satellites. The five currently operating GTE Spacenet satellites were all launched by Ariane.

G-Star III was to have been positioned in geostationary orbit at 124 degrees West, however during its move to this point the satellite veered off course and is now in a useless orbit. The cause of the failure has not been positively determined but suspicion has fallen on the apogee kick motor, a crack in the nozzle seems likely.

GTE Spacenet is attempting to salvage some use from the satellite which is expected to be declared a $60 million loss.

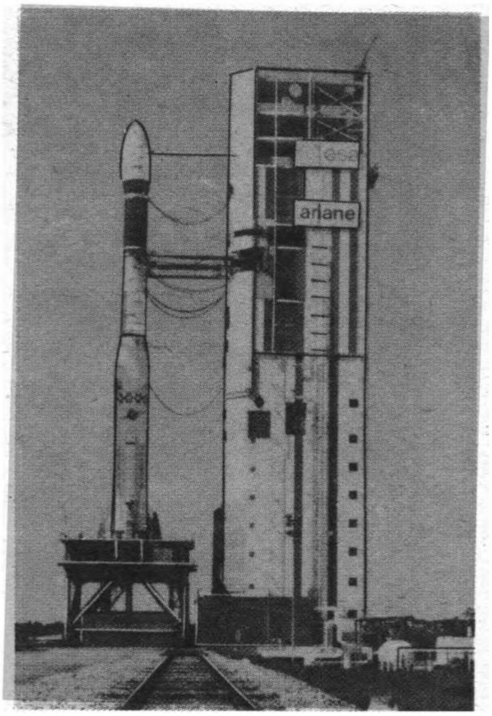
The GTE Spacenet satellite network offers private channels for business use. Its customers include; K Mart Corporation which is to use the satellites for communications between its headquarters and its 2,100 stores across the US. The United States Secret Service will use the system to provide a secured nationwide telecommunications network. Another of GTE Spacenet's customers is Day Inns of America which is the first hotel chain to handle reservations via satellite.

The satellites can offer video teleconferencing and satellite news gathering for television companies.

SBS-5

The SBS-5 satellite is the second in a series of HS-376 spin stabilized satellites built by the Hughes Aircraft Company for the Satellite Transponder Leasing Corporation (STLC). The first of this series SBS-4 was launched on the Shuttle during STS 41-D in August 1984, a third satellite, SBS-6 is under construction. The satellite is positioned at 122 degrees West.

The STLC satellite network has many applications. It is used by US companies to broadcast training videos and company news to employees in far-flung locations. Television companies use the system to provide "from the scene" news coverage, live pictures are transmitted to the studios via satellite from mobile ground stations in vans.



The Ariane 3 stands on the pad prior to its launch from the Kourou Space Center. *Arianespace*

Israel Launches Satellite

Israel launched its first satellite at 1132 (local time) on September 19, from a launch site South of Tel Aviv. News of an imminent Israeli launch was leaked to the press despite attempts to keep the lift-off secret. No photographs of the launch were released.

The satellite, named Horizon 1, is the first to orbit East to West, it is the usual practice to launch West to East. The Earth's spin will then assist the payload into orbit. Israel cannot take advantage of the Earth's rotation because safety requirements prevent the launch of satellites over populated areas. Israel's only coast line is with the Mediterranean and so the launch vehicle blasted off across the sea, East to West.

Professor Dror Sade Co-ordinator of the Israeli Space Agency said. "This is just a technological satellite; it is meant to determine whether Israel can enter space. Its transmissions do not include any information since the satellite is not equipped with instruments capable of relaying information. The transmissions are relayed by telemeters that emit meaningless signals, and at the moment we are only checking whether we can receive them.

"Each orbit lasts 90 minutes. There are 16 such orbits a day but only seven of them – each one lasting approximately seven minutes – take place over antennas in Israel." He continued.

It was suggested the Israeli space programme's main aim was to launch a spy satellite to monitor the country's Arab neighbours. Professor Yuval Ne'eman, Director of the Israeli Space Agency, answered these allegations. "All this work has security potential, but that is a matter for the security authorities: whether they want to exploit that potential or not. The importantance of the satellite at the moment is of a technological nature."

Both the launch vehicle and satellite were developed and constructed within Israel. Horizon 1 was built by Israel Aircraft Industries, which also intends to build Amos, Israel's first communications satellite.

Because of Horizon 1's low orbit it was expected to reenter after just one month, but it now seems likely that the satellite will remain in orbit for three weeks longer than expected.

Israel now joins the seven other countries to independtly launch their own satellite, namely, the Soviet Union, the US, France, Japan, China, the UK and India.

Insat Suffers Power Loss

Soon after launch by Ariane in July (*Spaceflight*, September 1988, p.346) the Indian communications satellite Insat-1C lost one of its two power buses. Indian space officials have now decided to use the satellite at reduced capacity. Insat-1C is operating full meterological services but only 50 per cent of its telecommunications capacity.

The chairman of the Indian Space Research Organisation, Prof. Rao said that with the loss of one electrical bus, "the spacecraft has lost the redundancies in some vital sub-systems such as telemetry, telecommand and attitude and orbital systems."

With one power bus delivering 50 per cent of the required power, six C-band transponders (as against 12), one S-band transponder (as against two), the radiometer instrument and the data relay transponder can be operated, Prof. Rao said. "All these payloads including the meterological imaging system have been cleared for use."

The Indian Space Research Organisation is looking into the need for corrective measures on Insat-1D due to be launched in April 1989,

Prof. Rao also gave details of the Augmented Satellite Launch Vehicle (ASLV) failure (***Spaceflight***, September 1988, p.349). The accident was due to a failure of the flight control system which led to the yaw and roll rate of the vehicle building up, the top portion of the booster broke up 50.4 seconds after launch. The Ross-2 satellite plunged into the ocean 257 seconds after launch.

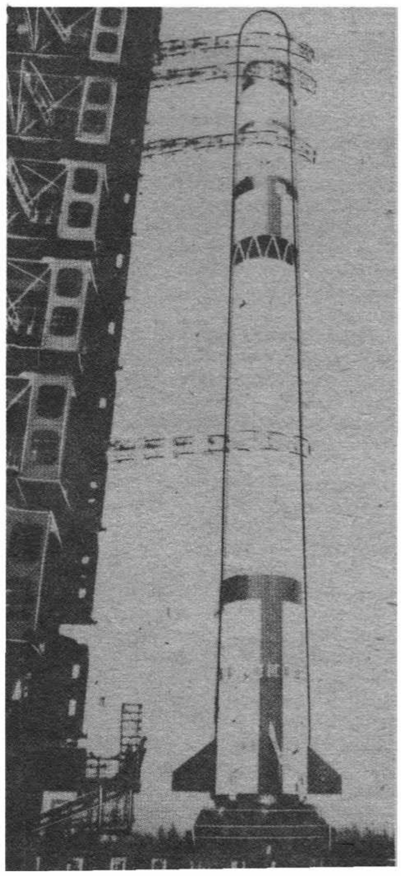
New Expendable Manifest

Date	Launch Vehicle	Orbit	Launch Site	Payload
		1989		
May	Delta 184	SS	WSMC	COBE
May	Atlas 50E	SS	WSMC	NOAA-D
September	Atlas Centaur 68	GSO	ESMC	FLTSATCOM-F8
		1990		
February	Delta	LEO	ESMC	ROSAT
February	Scout S-218C	LEO	WSMC	Transit-27
June	Atlas Centaur	GTO	ESMC	CRRES
July	Atlas Centaur	GSO	ESMC	GOES-1
August	Scout S-210C	LEO	WSMC	Transit-28
September	Atlas 34	SS	WSMC	NOAA-1
		1991		
May	Titan IV IUS	EO	ESMC	Planetary Alt.
June	TBD	LEO	TBD	Small Expl-01**
August	Delta	LEO	ESMC	EUVE
September	TBD	LEO	TBD	Small Expl-02**
October	Scout S-215C	LEO	SMR	CRRES
November	Atlas Centaur	GSO	ESMC	GOES-J
December	Atlas 11E	SS	WSMC	NOAA-J
		1992		
January	TBD	LEO	TBD	Small Expl-03**
May	Atlas Centaur	GSO	ESMC	GOES-K
June	TBD	LEO	TBD	Small Expl-04**
July	TBD	HE	ESMC	GEOTAIL
September*	Titan III	EO	ESMC	Mars Observer
December	TBD	HE	ESMC	WIND
		1993		
January	TBD	LEO	TBD	Small Expl-05**
March	TBD**	GSO	ESMC	MSAT**
April	Titan II**	SS	WSMC	NOAA-K
June	TBD	HE	WSMC	POLAR
June	TBD	LEO	TBD	Small Expl-06**

*Not before this date **For NASA planning purpose.

GLOSSARY

COBE Cosmic Background Explorer
CRRES Combined Radiation Release Experimental Satellite
EO Escape Orbit
ESMC Eastern Space and Missile Center (Cape Canaveral Air Force Station)
EUVE Extreme Ultraviolet Explorer
FLTSATCOM Fleet Communication Satellite
GOES Geostationary Operational Environmental Satellite
GSO Geosynchronous Orbit
GTO Geosynchronous Transfer Orbit
IUS Inertial Upper Stage
LEO Low Earth Orbit
MSAT Mobile Satellite
NOAA National Oceanic and Atmospheric Administration
ROSAT Roentgen Satellite
SMR San Marco Range
SS Sun Synchronous Orbit
TRANSIT Navy Navigation Satellite
WAMDII Wide Angle Michelson Doppler Imaging Interferometer
WSMC Western Space and Missile Center (Vandenberg Air Force Base)



The Long March 4 launch vehicle.

Three Firsts For China

The Chinese space programme has celebrated three firsts; the maiden flight of a Long March 4 blasted off from a new launch site, carrying China's first Sun-Synchronous weather satellite.

The Long March 4 blasted off from the new launch complex at Taiyuan in Shanxi Province at 8:30 pm GMT on September 6. The Long March 4 is capable of lifting 2,500kg to Sun-Synchronous Orbit (SSO). It uses the same design as the previous Long March vehicles.

The meterological satellite, named Fengyun-1 (meaning wind and cloud), is the first Chinese satellite to be launched into a polar SSO. The satellite is equipped with two very-high resolution scanning radiometers. It is capable of surveying cloud in daytime and at night, taking Earth surface and marine water colour pictures and monitor coverage of ice and snow. It is also capable of surveying the composition of particles in space.

The satellite can produce digital cloud charts with a resolution of 1.08 km in the high resolution picture transmission form and analogue cloud charts with a resolution of 4 km in the automatic picture transmission mode. The satellite weighs 750 kg and is the shape of a hexahedron.

INTERNATIONAL SPACE REPORT

Titan 34D Fails
Titan 2 Succeeds

The US military space programme has had both a setback and a success. A Titan 34D failed to place its payload into geostationary orbit, but a Titan 2 successfully placed multiple satellites into polar orbit.

The launch of the Titan 34D was initially hailed a success by the Air Force, but it later emerged that the vehicle's upper stage had failed to re-ignite and circularise the satellite's orbit.

The Titan 34D was launched from the Cape Canaveral Air Force Station at 8:05 am (EDT) on September 2. There was an aborted attempt to launch this Titan on June 25 when a ground equipment failure halted the countdown at T-2 seconds. There were fears the vehicle could explode on the pad.

The Titan 34D was believed to be carrying a Vortex electronic surveillance satellite, with a huge antenna capable of monitoring radio and telephone communications.

This is the third Titan 34D failure since August 1985. In the same period there have been just two successful launches.

Meanwhile the first Titan 2 missile to be converted for use as a satellite launcher placed a military payload into polar orbit after a launch from Vandenberg Air Force Base on September 5.

The Titan 2 was thought to be carrying a "White Cloud" Navy Ocean Surveillance System. There was one minor hitch when the Titan's first stage exploded soon after separation, a shock wave from the second stage ignition was thought to be responsible. The explosion did not affect the vehicle's ascent.

NASA Buys Second Shuttle Carrier Aircraft

NASA has signed a contract with Boeing Military Airplanes to modify a Boeing 747-100 for use as a second Shuttle Carrier Aircraft (SCA).

NASA announced plans to acquire a backup SCA in February of this year. The airplane selected is nearly identical to the original SCA which will minimise costs associated with modifications.

The work will be accomplished at Boeing facilities in Wichita and will include structural modifications to enable attach pylons to be mounted atop the aircraft and additional changes to permit better flight control during ferry flights. The agreement calls for delivery of the backup SCA in October of 1990.

The cost-plus-fixed fee contract is valued at $55 million.

Space Station Agreement Signed

The partners in the international Freedom Space Station project signed an agreement on September 29.

The signing ceremony took place at the US State Department in Washington DC. Each of the ESA countries involved, Japan, Canada and the US signed an agreement and a Memorandum of Understanding (MOU).

Under the MOU 46 per cent of the European Columbus Laboratory will be used by NASA, who will provide the transport to orbit and the space station's utilities, e.g. power, thermal control etc. Three per cent of the European laboratory will be allocated to Canada, in return for the use of the Mobile Servicing Centre which it will supply.

Funding for the European participation in the project is as follows:

Germany	38.0%
Italy	25.0%
France	13.8%
Spain	6.0%
United Kingdom	5.5%
Belgium	5.0%
Netherlands	1.3%
Denmark	1.0%
Norway	0.4%

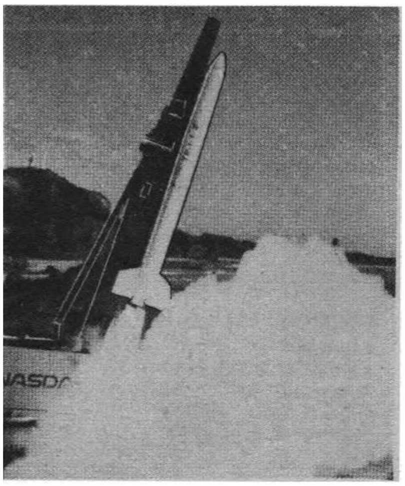
Japan Tests H-II Concept

The National Space Development Agency of Japan (NASDA) has launched a scale model of the H-II rocket. The test was part of the development programme for Japan's next generation launch vehicle.

The Test Rocket-1 (TR-1), powered by a single solid rocket motor, is one quarter the size of the H-II launch vehicle, weighs about 11.8 tons and is 14.3m in length. It is an exact replica of the H-II apart from four tail fins-which the model uses for flight stability.

The TR-1 was launched from the Tanegashima Space Center at 8:00 am (JST) on September 6, with a launch elevation of 75.7 degrees and azimuth of 92.8 degrees. 49 seconds after launch the two dummy SRBs were successfully separated and the recovery portion splashed down on its parachute. The portion was recovered by a ship later that morning 100 km East of Tanegashima Island. The rocket's central stage reached a maximum altitude of about 85km before plunging into the ocean.

The TR-1 is launched from the Tanegashima Space Center. *NASDA*



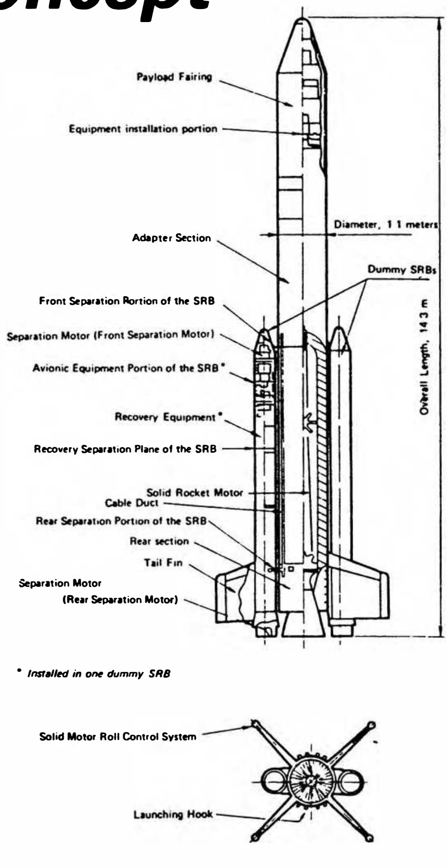
The aim of the TR-1 programme is to obtain useful information for the final development of the H-II. Onboard sensors measure the following:

- Aerodynamic heating
- Pressure
- Acoustics
- Atmospheric interference
- Coefficient of rocket resistance
- Thermal radiation from exhaust plume

A second objective is to test the Solid Rocket Booster (SRB) separation mechanism. The TR-1 has two small no-burn dummy SRBs.

One of the dummy boosters carries recovery equipment and on later flights will also contain a data recorder. After SRB separation the recovery portion of the booster is disconnected from the SRB. A pressure switch releases a parachute at an altitude of 6km, the water-tight recovery portion then splashes down at sea. A flotation bag is released, a homing beacon and dye marker make the section easily locatable for recovery.

This was the first of three launches for the scale model, the second will take place this winter and the third next summer.



Configuration of the TR-1.

SATELLITE DIGEST — 216

A monthly listing of satellite and spacecraft launches, compiled from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

Robert D. Christy

Continued from the October 1988 issue

COSMOS 1945, 1988-42A, 19131
Launched: 0915, 19 May 1988 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 12 days.
Orbit: 232 x 321 km, 90.09 min, 70.37 deg.

COSMOS 1946-1948, 1988-43A-C, 19163-19165
Launched: 1757, 21 May 1988 from Tyuratam by D-1-e.
Spacecraft data: not available.
Mission: Navigation satellites in GLONASS (the Global Navigation Satellite System).
Orbit: 19114 x 19144 km, 675.71 min, 64.92 deg.

MOLNIYA-3 (32), 1988-44A, 19189.
Launched: 1525, 26 May 1988 from Plesetsk by
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communciations satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and abroad.
Orbit: Initially 611 x 40705 km, 737.36 min, 62.82 deg, then lowered to 587 x 39782 km, 737.51 min, 62.81 deg, to ensure daily repeats of the ground track.

COSMOS 1949, 1988-45A, 19193
Launched: 0245, 27 May 1988 from Tyuratam by F-1.
Spacecraft data: Cylindrical, probably about 7 m long and 2 m diameter, equipped with solar cell panels and with a mass around 5000 kg.
Mission: Electronic intelligence gathering over ocean areas.
Orbit: 403 x 418 km, 92.79 min, 65.04 deg, maintained by a low thrust motor during the operational lifetime.

COSMOS 1950, 1988-46A, 19195
Launched: 0802, 30 May 1988 from Plesetsk by F-2.
Spacecraft data: Possibly similar to the navigation satellites, having a cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. The mass is around 700 kg.
Mission: Geodetic satellite.
Orbit: 1484 x 1522 km, 116.10 min, 73.61 deg.

COSMOS 1951, 1988-47A, 19197
Launched: 0745, 1 June 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system, and a 2m diameter, 0.5m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered after 13 days. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 259 x 275 km, 89.92 min, 82.33 deg.

SOYUZ-TM 5, 1988-48A, 19204
Launched: 1403*, 7 June 1988 from Tyuratam by A-2.
Spacecraft data: Near-spherical orbital compartment carrying a rendezvous radar tower, conical re-entry module and cylindrical instrument unit with a pair of solar panels, and containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried Soviet/Bulgarian crew of Anatoly Solovyev, Viktor Savinikh and Alexander Alexandrov to Mir. Docking with Mir's rear port occurred at 1557 on 9 June. The crew returned to Earth in Soyuz-TM 4, landing at 1013 on 17 June. At 0911 on 18 June, with Titov and Manarov aboard, it undocked and then re-docked at Mir's forward port, 16 minutes later.
Orbit: Initially 198 x 216 km, 88.58 min, 51.62 deg, then by way of a 281 x 340 km transfer orbit to a docking with Mir in an orbit of 349 x 355 km, 91.52 min, 51.62 deg.

COSMOS 1952, 1988-49A, 19206
Launched: 1000, 11 Jun 1988 from Tyuratam by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recoverd after 14 days.
Orbit: 230 x 287 km, 89.71 min, 69.99 deg.

COSMOS 1953, 1988-50A, 19210
Launched: 0319, 14 June 1988 from Plesetsk by F-2.
Spacecraft data: Possibly a truncated cone with a pair of Sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation may either be by the use of a gravity gradient boom or by momentum wheels.
Mission: Electronic intelligence gathering.
Orbit: 635 x 667 km, 97.79 min, 82.53 deg.

METEOSAT 3, 1988-51A, 19215
Launched: 1119*, 15 June 1988 from Kourou by Ariane 44LP (V-22)
Spacecraft data: Cylindrical, spin-stabilised, solar-cell covered body, 2.1 m diameter and 3.1 m high, with mass 696 kg (fuelled).
Mission: European meteorological satellite returning cloud cover images and other weather data from geosynchronous orbit.
Orbit: geosynchronous above 10 deg west.

OSCAR 13, 1988-51B, 19216
Launched: 1119*, 15 June 1988 from Kourou by Ariane 44 LP (V-22)
Spacecraft data: Three-pointed star shaped prism, approx 1 m across. The mass is 150 kg (incl 60 kg of manoeuvering fuel.
Mission: Amateur-radio relay satellite.

Orbit: 1087 x 36094 km, 653.92 min, 14.26 deg, later to be manoeuvered to a 57 degree inclination orbit at similar height.

PANAMSAT 1, 1988-51C, 19217
Launched: 1119* 15 June 1988 from Kourou by Ariane 44LP (V-22)
Spacecraft data: Box-shaped body, 1.6 x 1.3 x 1.3 m, with twin-panel solar array approx 10 m across. The mass is 1220 kg (fuelled).
Mission: US domestic communications satellite equipped with C-band and Ku-band transponders.
Orbit: geosynchronous above 45 deg west.

NOVA 2 (3), 1988-52A, 19223
Launched: 0619*, 16 June 1988 from Vandenberg by Scout
Spacecraft data: Octagonal prism with four solar panels at right angles to the centre line of the body, approx 0.5 m diameter and 1 m long. Stabilisation is by way of a gravity gradient boom, the mass is 165 kg.
Mission: US Navy navigation satellite
Orbit: Initially 312 x 945 km, 97.35 min, 90.14 deg, then manoeuvred to an operational orbit of 1154 x 1202 km, 109.01 min, 90.06 deg by an on-board thruster.

COSMOS 1954, 1988-53A, 19256
Launched: 1629, 21 June 1988 from Plesetsk by C-1.
Spacecraft data: Possibly a cylindrical, solar cell covered body, 2 m long and 2 m diameter with mass around 700 kg.
Mission: Military communications using a store/dump technique.
Orbit: 780 x 806 km, 100.77 min, 74.05 deg.

COSMOS 1955, 1988-54A, 19258
Launched: 1300, 22 June 1988 from Tyuratam by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical camera module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A supplementary equipment package may be fitted at the forward end. Several small, heat shielded containers may be carried for periodic return to Earth of film. The overall length is about 6 m, maximum diameter 2.4 m and the mass around 7000 kg.
Mission: Military photo-reconnaissance over an extended period.
Orbit: 258 x 273 km, 89.83 min, 64.76 deg, manoeuvrable.

COSMOS 1956, 1988-55A, 19263
Launched: 0745, 23 June 1988 from Plesetsk by A-2.
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered.
Orbit: 333 x 368 km, 91.61 min, 82.30 deg.

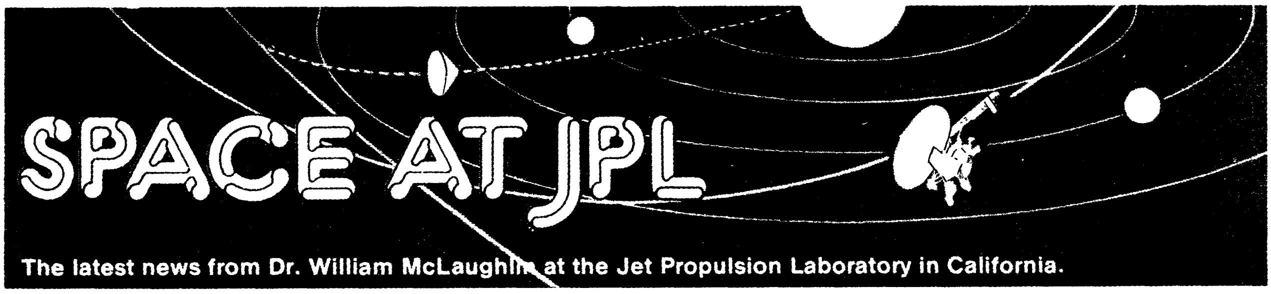
The first image returned by Meteosat 3 at 13:30 GMT on June 29, 1988. *ESA/Eumetsat*

OKEAN 1, 1988-56A, 19274
Launched: 0946, 5 July 1988 from Plesetsk by F-2.
Spacecraft data: Truncated cone with a pair of Sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array, including a 13 m long radar aerial at the larger end. The length is probably about 4 m, maximum body diameter 1.5 m and mass around 1600 kg. Stabilisation is by the use of a gravity gradient boom.
Mission: Oceanographic satellite equipped with a sideways-looking radar and other remote sensing systems to return images of the world's sea-surface.
Orbit: 635 x 666 km, 97.81 min, 82.52 deg.

COSMOS 1957, 1988-57A, 19276
Launched: 0800, 7 July 1988 from Plesetsk by A-2.
Spacecraft data: Possibly based on the Vostok manned spacecraft and consisting of a spherical re-entry module with a conical instrument unit containing batteries, control equipment and a rocket motor system and a 2m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Photo-reconnaissance, recovered. All or part of the payload was an Earth resources package operating under the 'Priroda' programme.
Orbit: 260 x 275 km, 89.92 min, 82.59 deg.

PHOBOS 1, 1988-58A, 19281
Launched: 1738*, 7 July 1988 from Tyuratam by D-1-e.
Spacecraft data: Standard Soviet Venera-type body with an additional, propulsion stage at the 'lower' end and a dish aerial at the other. Power is provided by a pair of 'horizontal' solar panels at right-angles to the body. The mass is around 6000 kg.
Mission: Planetary exploration craft heading for Mars and the Martian moon, Phobos.
Orbit: heliocentric

PHOBOS 2, 1988-59A, 19287
Launched: 1701*, 12 July 1988 from Tyuratam by D-1-e.
Spacecraft data: Standard Soviet Venera-type body with an additional, propulsion stage at the 'lower' end and a dish aerial at the other. Power is provided by a pair of 'horizontal' solar panels at right-angles to the body. The mass is around 6000 kg.
Mission: Planetary exploration craft heading for Mars and the Martian moon, Phobos.
Orbit: heliocentric



Deep-Space Laser Communications

Interplanetary spacecraft collect copious quantities of valuable scientific data. Telecommunications systems have, since the flight of Mariner 2 to Venus in 1962, utilised radio frequencies to transport these data from the antenna on the spacecraft to the antenna on the ground. Numerous strategies have been devised to increase the capacity of this electromagnetic link. An obvious approach is to build larger ground antennas, and the latest augmentation of aperture for NASA's Deep Space Network has transformed the three 64 m antennas to 70 m each (see the January 1988 edition of this column). Onboard the spacecraft, data compression techniques and more efficient, higher frequency systems have increased the flow. Dr. Marc Rayman and his colleagues at JPL are currently designing laser systems with which they hope to satisfy the ever-increasing data demands of future deep-space missions.

The ubiquitous laser serves the needs of the modern world in areas ranging from medicine and manufacturing to telecommunications. "Laser" is an acronym which represents the phrase "light amplification by stimulated emission of radiation". The laser emits its light in the ultraviolet, visible, or infrared regions of the spectrum while its cousin, the maser, produces microwaves: hence the "m". The maser, invented by Charles Townes of Columbia University in the early 1950's, preceded the laser

There are numerous methods for producing laser beams, but it is possible to give a generic description of the process and, as a result, gain an appreciation of the properties from which the utility of this advice is obtained First, it is useful to call to mind the modern picture of the atom, developed by the Danish physicist Niels Bohr (1885-1962)

The Bohr atom, like the atomic model of Ernest Rutherford (1871-1937), consists of a nucleus surrounded by a swarm of electrons. To this picture Bohr added Max Planck's (1858-1947) idea that, in the microworld of the atom, energy is quantised and not able to assume just any value. The result is a nucleus orbited by electrons at definite, discrete energy levels, lower energies being closer to the nucleus In the Solar System, the planets are analogous to electrons and the Sun to the nucleus, and inner planets have lower mechanical energy than outer ones; but these energies are not quantised. However, J.M. Barnothy, in *The Stability of the Solar System and of Small Stellar Systems*, Y. Kozai, editor, 1974, suggested that the solar system is quantised, and, in another speculation on macroworld quantisation, it has been proposed that galactic velocities are quantised; see the January 1987 *Sky and Telescope*, pp.19-21. Neither theory is generally accepted.

When an electron drops from a higher energy level to a lower one, a photon is emitted from the atom and possesses an energy equal to the energy loss of the electron when it transitioned to the lower level. Since energy determines wavelength (moving from the photon model to the wave model of electromagnetic energy), this explains how a particular type of atom is characterised by the "colour of light" it can emit: spectral lines. The reverse process can occur when an atom absorbs a photon, of suitable energy, increasing the energy level of one of its electrons. If the absorbed photon has sufficiently great energy, an electron can be ejected from the atom altogether. This "photoelectric effect" was explained by Albert Einstein (1879-1955) in terms of the quantum theory, an analysis for which he was awarded the 1921 Nobel Prize in physics.

In the normal state, when a collection of atoms is in a state of thermal equilibrium, the lower energy levels of these atoms are preferentially populated with electrons; the lowest or ground level of energy is most populated of all

Townes, while sitting on a park bench, conceived the idea of pumping energy into a collection of atoms to raise many of their electrons to higher energy levels ("a population inversion" as it is called in this context) and then stimulate the atoms into a massive emission of single-frequency microwaves by introduction of a small amount of "seed" microwaves of the desired frequency.

The basic constituents, then, of a laser are threefold: a material that will "lase", a source of energy to raise the electrons in this material to higher energy levels, and a resonant system that will encourage stimulation of an avalanche of photons – lasing – in a single direction

The first laser, the ruby laser built in the late 1950's, supplies a concrete example of the functioning of these constituents. The ruby crystal contains a small amount of chromium which serves as the lasing material. An apparatus surrounding the crystal flashes light onto the ruby, pumping an electron in each of a large number of chromium atoms (in ruby, these atoms are ionised but we ignore the atom/ion nomenclature as irrelevant here) to a high energy level. This high energy state is rapidly depleted by the spontaneous transitioning of the excited electrons to a slightly lower energy level which is, fortunately, comparatively stable ("metastable"); the electrons will remain in this elevated energy level long enough for the coordinated lasing process to be effected. The dwell time of an electron in the metastable level is about 4,000,000 nanoseconds (ns) compared to some 10ns or less for non-metastable levels; a nanosecond is a thousand millionth of a second. Population inversion has been accomplished.

When the first few electrons do (spontaneously) transition from the metastable energy level to the lower level, photons are emitted according to the Bohr model. The associated wavelength of light from the ruby laser is 0.6943 microns, which lies in the red portion of the spectrum.

So far, all has proceeded according to the principles of ordinary atomic physics; no lasing has occurred. Recall that from the Bohr model one would expect these newly created photons, if they encounter an atom, to be absorbed and raise an electron of that atom to a higher energy state. However, there is a second process that can also take place as a result of the interaction of a photon with an atom: stimulated emission If the atom has an electron already in a higher energy state, then the encounter can induce the electron to drop to a lower energy level, emitting, consistent with Bohr's model, a photon (of the same energy as the one that stimulated the emission). Thus, two photons are now present where there was only one. The process produces a rapid cascade of photon emission from the chromium atoms; lasing has begun

It can be shown that during a photon-atom encounter the probability of a photon being absorbed by the atom, raising an electron to a higher energy state, equals the probability of stimulated emission of a second photon (if the atom is already excited). Normally, most atoms are not excited, but under laser conditions of population inversion, the stimulated emission predominates

The third constituent of the ruby laser is the provision of a silvered reflecting surface at one end of the rod comprising the ruby crystal and a parallel semi-silvered surface at the other end These mirrors, properly spaced, serve two functions. First, they force photons to bounce back and forth, increasing the effective number of stimulating agents for the lasing process. Second, they define a preferential direction for the emissions to travel – photons emitted in other directions do not participate in the final laser beam. That beam is transmitted out of the system, for use, through the partially silvered mirror.

Hence, a laser produces a concentrated beam of light of a single colour. That beam is also "coherent" – very important for many applications but not for the particular

scheme employed by Rayman and his colleagues – that is, the electromagnetic fields associated with the light bear a determinable, non-random relation to one another and not the chaotic mix associated with ordinary sources of light such as lamps. Coherence arises from the lock-step induced by the stimulation mechanism.

The value of the concentrated beam for interplanetary communications is that power is not lost to the receiver by excessive spreading of the transmitted energy during its traverse of space. As an example, Rayman says that the radio signal (X-band) from Voyager at Saturn filled a pattern about 2500 times the diameter of Earth, at Earth, while a 0.532 micron laser transmitted through a 10 cm telescope from Saturnian distance would produce a footprint approximately the size of Earth; this represents a power-density increase of a factor of over six million and gives some indication of the potential of optical communications. The received laser beam is concentrated because it started out that way due to its mode of production and, it is a fact about electromagnetic waves, that ones of high frequency diverge less than do ones of low frequency.

Of course, on Earth there is scattering of laser light due to the atmosphere so that one can see a laser beam "from the side" just as one can see a flashlight beam.

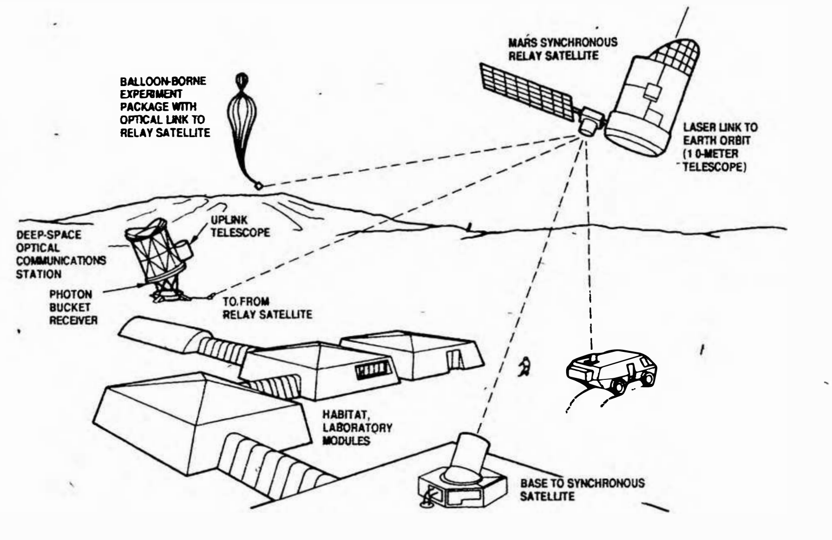
The second great advantage of optical communications over radio links also depends upon the higher frequency of the former.

More information can be carried by a higher frequency electromagnetic wave. The information-carrying scheme that Rayman and his colleagues are using is called pulse-position modulation (PPM).

The PPM concept is quite simple to understand. Imagine a window of time divided, for example, into eight equal parts, labelled 0 through seven. In order to transmit the number six from spacecraft to Earth, the laser system emits some marker photons into the time slot labelled six. Since all data can be encoded into numbers (usually binary numbers are utilised; six equals 110 in binary notation, a three-bit binary number), filling an appropriate series of time slots with photons suffices to transmit the data generated by the spacecraft. In order to interpret correctly the received signals, a clock on Earth must be tied to a precise clock on the spacecraft.

Typically, from 10 to 100 marker photons are received in a time slot, though many more are started on the journey from spacecraft to Earth. While in principle only one photon would be required, photons from other sources ("noise") creep into the time slots. In the PPM example given above, three bits were transmitted (see "Measuring Information" in the April 1988 edition of this column – a bit is a measure of the amount of information and a picture usually requires several million bits to describe). If only one photon were used as a marker in the above 8-slot example, this would represent a highly efficient three bits per photon, but 0.01 to 0.1 bits per photon is more typical in practice. Rayman's group have demonstrated in the laboratory rates as efficient as 2.5 bits per detected photon.

The laser being developed for interplanetary applications uses the element neodymium as the active material for lasing (analogous to chromium in the ruby laser), and it is held in an inert host matrix. Increased efficiency is achieved over the flash-lamp approach by pumping the electrons in the neodymium to higher energy levels (population inversion) by another laser tuned precisely to the desired energy setting.



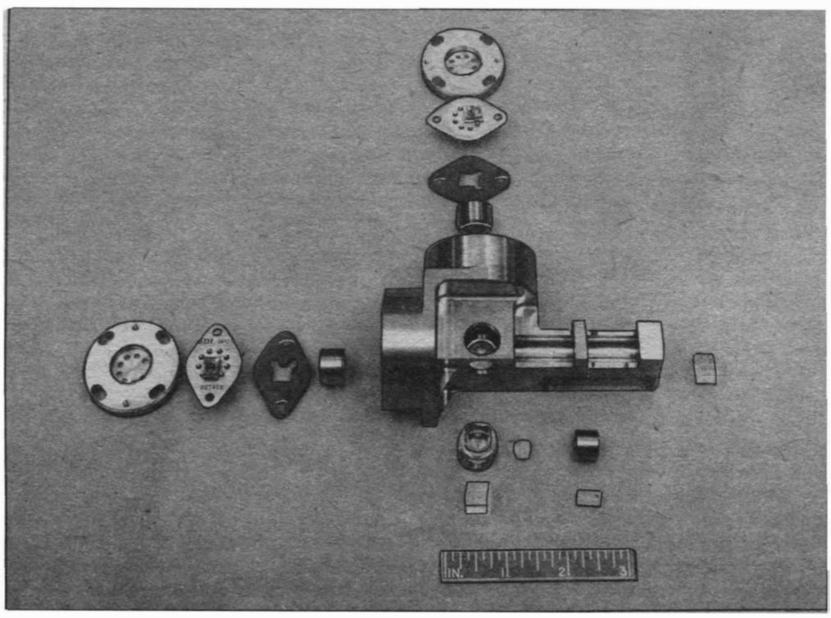
This schematic depiction of a base on Mars shows the communications links via lasers that would facilitate a data-rich and broadly based program of exploration. *NASA/JPL*

The basic output of this laser is light in the near infrared at a wavelength of 1.06 microns. However, detectors in this range are not highly efficient, therefore the frequency of the laser output is doubled (wavelength halved) before transmission, yielding a green-light beam.

The anticipated benefits from laser telecommunications have been indicated in a general way by referring to concentration of signal strength and increased bit rates, both advantages relative to radio frequencies. More specifically, a baseline design for a mission to Saturn has shown that a 50 kg communications package, consuming 60W of power, could return 200 kilobits per second of data to Earth, under favourable weather conditions. This scenario envisages a 30 cm telescope transmitting at 1 w from the spacecraft, sending signals with the 0.532 micron (green light) neodymium laser mentioned above. The Voyager spacecraft returned a maximum of 44.8 kilobits per second from Saturn. Rayman hopes to include a laser telecommunications demonstration on a future interplanetary mission, possibly on the proposed Cassini mission to Saturn (see the August 1988 "Space at JPL" for a mission description). Then, the goal is to incorporate laser telecommunications as a standard feature of spacecraft design.

Atmospheric interference is a problem facing laser telecommunications; clouds block visible light, whether it originates from the Sun or from a laser. One solution, in the long term, is to locate receivers in orbit or on the Moon. For the nearer term, Rayman is prospecting for meteorologically favourable sites on Earth – ones that have reasonably clear weather and are uncorrelated with one another with respect to cloud cover, or even negatively correlated. To assist in this study, three telescopes are being placed in automated facilities in the southwestern US to compile

The components are displayed for a Laboratory prototype of a laser for use onboard a spacecraft to serve telecommunications needs. Future developments might yield very small devices to function onboard microspacecraft of the 5 kg class. *NASA/JPL*



accurate atmospheric-transmission statistics.

A second mission that could serve as a test for laser telecommunications is the Mars Rover Sample Return (MRSR is discussed in the November 1987 edition of this column). Using as an optical transmitter the camera on the MRSR orbiter, an instrument which would primarily be used for landing-site selection for the rover system, 20 megabits per second of data could be sent to a 10 m-receiver on Earth. The mirror for the 10 m-telescope need not be shaped to exacting standards for the task of collecting message-bearing photons; a surface fidelity of two microns, four times the wavelength of the incident laser signal, would suffice (astronomical practice normally requires a mirror-shaping precision of about one-tenth of the wavelength of the incident electromagnetic waves). This reduction in requirements would greatly decrease the cost of the optical receiver, which would also benefit from technology-development work underway for the proposed Large Deployable Reflector described in the February 1988 "Space at JPL".

A Thousand Astronomical Unit (TAU) mission study, reported in the January 1987 *Spaceflight*, would range beyond the realm of the planets to make astrometric measurements on a long baseline, in conjunction with Earth-based telescopes. Using a laser link, the return of data from this possible mission would be at rates as high as 20 kilobits per second at 1000AU, the same rate at which Voyager 2 returned data from Uranus, 50 times nearer, at radio frequencies. An efficiency of 1 bit per detected photon is assumed for this estimate. In order to achieve this data rate at 1000AU, with radio frequencies (Ka band), a 10 m antenna onboard the spacecraft would be required, as well as a 200 m ground-based receiver The optical hardware requirements are much more modest with a 1 m onboard telescope feeding a 10 m telescope orbiting Earth.

If a base is eventually established on the Moon, very high data rates to and from Earth would probably be required to support surface activities, suggesting the use of laser telecommunications. A favourable site for radio astronomy is the far side of the Moon, which is shielded from Earth-generated interference at radio frequencies. An optical relay satellite could be positioned at a Lagrangian point in continuous view of the far-side base and Earth. Rayman estimates that with 30 cm-telescopes and 1W lasers at the lunar base, the relay satellite, and a geosynchronous satellite in Earth orbit (with a radio-frequency link to the ground), data could be sent to and from the lunar base at the extremely high rate of 500 megabits per second.

The use of lasers benefits not only data systems but could be of value, in an ancillary role, for navigational purposes. From Saturnian distance the above-mentioned 1W laser would appear as bright as an 11th magnitude star, making it easily visible in small telescopes on Earth. Astrometric techniques would permit measurement of the apparent location of the spacecraft with respect to nearby stars to an accuracy of 0.001 arc seconds, comparable with the results obtainable using very-long-baseline interferometric measurements at radio frequencies.

The timetable for the introduction of laser communications on a regular basis cannot be predicted with accuracy, but the growing capability of this medium makes its eventual use seem inevitable.

Microspacecraft Conference

On July 6-7 a distinguished group of scientists and engineers met at JPL to discuss how best to foster the development and use of "micro-spacecraft" – vehicles of about 5 kg mass – for exploration of the solar system. The primary motivation for reviewing the status of microspacecraft was to assess their potential for making it easier to get into space for the purpose of scientific exploration. Under current practices, cost and launch-vehicle constraints usually interpolate many years between a good mission idea and its realisation. For example, the Galileo mission to Jupiter was established as a project over a decade ago and is now scheduled for launch in 1989, arriving at Jupiter in late 1995.

There is a dual thrust in microspacecraft research. First, engineering efforts are underway to evaluate the possibilities for miniaturisation of familiar mechanisms such as cameras and power systems. Second, assuming a reasonable level of miniaturisation, missions are being designed and evaluated with regard to how much scientific information they might be expected to return. The outcome of these thrusts will determine whether or not microspacecraft flourish as a mechanical species within the Solar System. The conference, organised by Ross Jones and James Burke of JPL, was jointly sponsored by NASA's Office of Aeronautics and Space Technology and the Innovative Science and Technology Office of the Strategic Defense Initiative Organisation. The review panel for the two days of sessions included Professor Freeman Dyson of the Institute for Advanced Study at Princeton University and Dr. Robert Forward, a private consultant.

Due to the large number of presentations, only selected topics can be touched upon here. Some additional material is contained in "Science Seeds" in the April 1988 edition of this column

Proposals for launching micro-spacecraft have, to date, favoured electromagnetic facilities, e.g., railguns. In most scenarios, these devices would be located in Earth orbit and would speed the small spacecraft on their way at velocities of many kilometers per second (see the chart on p 153 of the April 1988 ***Spaceflight*** which shows how transit times to distant points in the solar system can be dramatically reduced for these small objects)

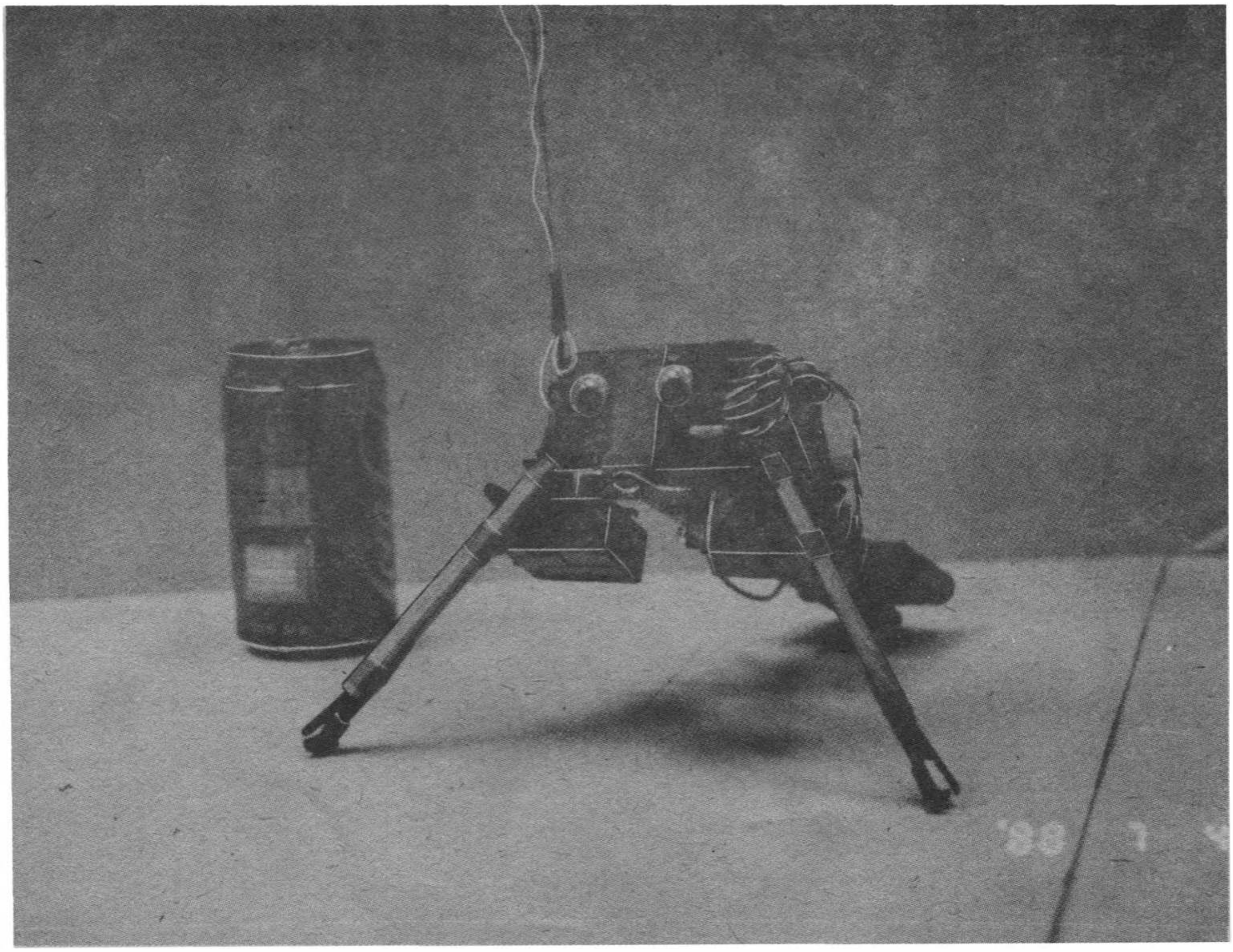
Mark Sargent of JPL discussed the use of chemical launchers for micro-spacecraft. Usually, one does not want to devote a large launch vehicle to the injection of a single microspacecraft into its interplanetary trajectory. One alternative is the "piggyback" approach which would include the small spacecraft as an adjunct to the larger main payload. The practice of piggybacking secondary payloads is not uncommon either with expendable launch vehicles or Shuttles. A launch strategy which is more customised for the microspacecraft domain is the shotgun method of clustering 70 to 100 of the small spacecraft on a Scout, Delta, Titan, Shuttle, etc.

In building a spacecraft with a mass in the neighbourhood of 5 kg, certain subsystems pose more-than-average problems for the scaling process, e.g., power generation, telecommunications, and imaging. Thomas Soulanille of Altadena Instruments presented the results of a conceptual design for a camera which might be accommodated onboard a microspacecraft. He foresees an instrument with a mass of approximately 1 kg and a power consumption of 2W (5W peak); this contrasts with classical systems of about 50 kg, consuming 30W to 50W of power. The camera design features a one-dimensional array of 2048 picture elements (pixels) in the focal plane, and these elements are scanned over the target body by rotation of the spacecraft. By contrast, the Voyager camera has an array of 800 x 800 pixels which are held steady on the target during image formation.

Microspacecraft need not be restricted to interplanetary cruisers; diminutive planetary rovers are also being considered. "Gnat Robots" in the August 1988 edition of this column outlined a series of small robots under development at the Artificial Intelligence Laboratory of the Massachussetts Institute of Technology (MIT). Professor Rodney A. Brooks, leader of the Mobile Robot Project at MIT, presented concepts for small planetary rovers and brought to the conference prototype models. The small rovers are about 1 kg in mass and feature a simple control system which reacts to environmental situations. This type of control system has been patterned by Brooks after examples from the animal kingdom, especially insects, and does not require extensive "world models" resident in a large central computer.

One small rover is already operational and uses two legs to drag itself around on a third point of contact – the tail. A more advanced, six-legged rover is being assembled and will be able to cope with more-difficult-to-navigate terrain. It will consume 10W of power to move its 1¼ kg body into positions of advantage for close-up imaging or other sensory services. A promising scenario for utilisation of insect-like rovers is to link them to a large (c. 500 kg) rover in a mother-daughter relationship. The large rover would provide the insects mission direction and tending services, while the smaller entities could be deployed in high-risk areas.

As mentioned above, it is essential to assess the scientific potential of microspacecraft. Several areas of promise were



A prototype of a simple two-legged rover has been developed at the Massachusetts Institute of Technology as part of microspacecraft studies. *MIT AI Lab*

explored, and three will be outlined: imaging, gamma-ray astronomy, and radio science.

Michael Ravine of Altadena Instruments characterised imaging applications through five descriptors: spatial resolution, spectral resolution, spatial coverage, temporal coverage, and data rates. Using these criteria, Ravine analysed some missions of focussed space science. For example, a simple camera for a Mars weather satellite should achieve a spatial resolution of 5 to 10 km (to resolve clouds); image in two colours (to distinguish water-ice clouds from dust clouds); provide global spatial coverage; supply this information on a daily basis; and generate about a megabyte of data per day. With design criteria such as these in mind, engineers can evaluate current imaging devices and plan future directions.

Gamma-ray astronomy addresses high-energy events such as the supernova discussed in the September 1988 issue. Dr. William A. Wheaton of JPL indicated how gamma-ray detectors carried onboard microspacecraft could be employed in the observation of certain transient events: gamma-ray bursts and solar flares. Gamma-ray bursts are somewhat mysterious rushes of electromagnetic waves in the region beyond x-rays; perhaps five or so big bursts are detected each year. Their origin is not known, but one hypothesis relates them to neutron stars. Flares on the Sun, resulting from the release of magnetic energy, can be observed in the gamma-ray region of the spectrum.

Since origin is an important question concerning gamma-ray bursts, the determination of the direction of each event is crucial. It turns out that four separated detectors, not in the same plane, suffice to define the direction. Monitoring the Sun for solar flares could be accomplished by placing approximately five microspacecraft in a heliocentric ring. The flares could be localised to the region of occurrence on the Sun and their depth in the solar atmosphere.

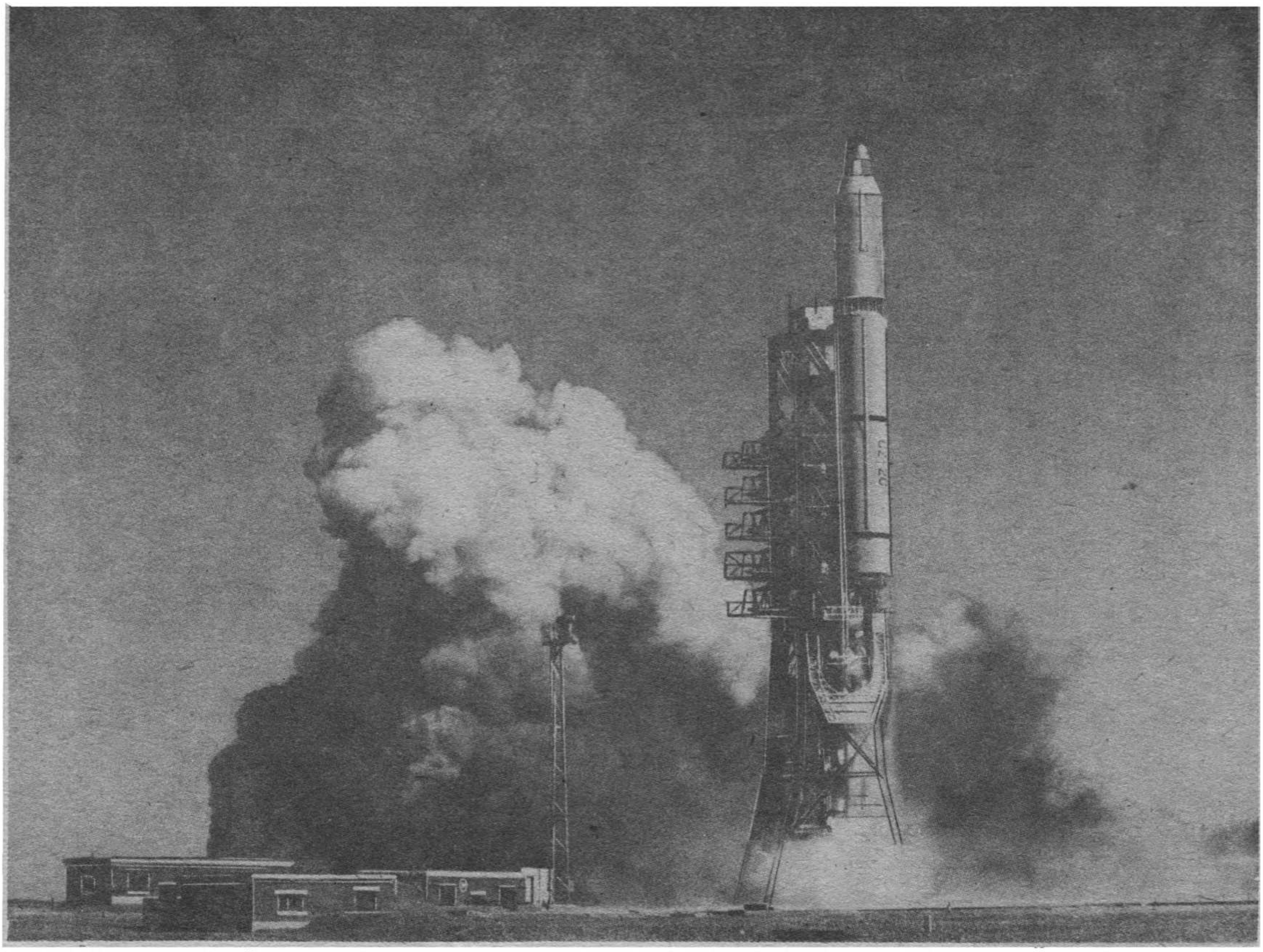
Detectors for gamma-ray transient events would require a mass of about 1 kg and a power source of 1W. If the power from the microspacecraft were drawn from a radioisotope thermoelectric generator (RTG), as opposed to solar power, high-energy emissions from the RTG would cause noise problems for the scientific detectors.

Radio science has been a valuable and efficient accompaniment to most deep-space missions. By analysing the radio signal from the spacecraft, a signal which is also used to return scientific data and engineering measurements of the spacecraft's state, properties of the medium traversed by the radio waves can be deduced. Accurate knowledge of the masses and gravitational fields of distant planets and satellites have been obtained in this manner, as well as the structure and composition of their atmospheres (when present), when the trajectory of the spacecraft permitted radio-occultation experiments.

Michael J. Connally of JPL proposed that microspacecraft be considered for use in several areas of radio science. Detection of hypothesized-but-elusive gravity waves could be attempted with three spacecraft sent on solar-system escape trajectories, separated by 120 degrees in longitude. Mapping of the heliospheric gravity field could also be done by this triad. In addition to atmospheric occultation experiments for planets and satellites, studies of the solar corona would benefit by a spacecraft placed in an anti-Earth orbit, but offset slightly to be visible (in the radio sense) through the solar corona. Connally envisaged increasingly detailed studies of the corona through placing additional spacecraft, up to perhaps 12, in a halo about the Sun.

Microspacecraft devoted to radio science could be quite simple. One would want to maximise the power in the downlink carrier, but no engineering telemetry would be required. Reduction of nongravitational forces would be important for gravity-science missions and would be facilitated by promoting a small area-to-mass ratio and minimising (or eliminating) thruster expulsions.

The sense of the conference was that microspacecraft represent an exciting and promising area for future applications. The cluster of ideas is not a solution to all the problems of space science, and more work is needed, but one should not be surprised to see these modern-day insects propagate through the Solar System.



A Long March 2 blasts off.

China Advances in Space

Space Minister Li Xue declared the Chinese Space Industry a competitor in the commercial space world in 1985. China's space programmes have since been opened to foreign inspection, answering many questions about the country's space capabilities. China continues to expose her space assets to foreigners – a situation not seen in previous years but which may now become better and familiar.

By G. Lynwood May

Sun Jiadong, Vice-Minister of Aeronautics Industry, indicates that China has shifted her emphasis from that of an international loner and has become a viable, emerging satellite launch alternative for all nations of the world. China launch services are being offered at a lower price than is available in the US or Europe. Launch insurance is underwritten by the Chinese government. Plans are underway to use China's under-utilized space capabilities in the areas of new multinational satellite developments, utilization of satellite data, advanced Chinese launch vehicle designs, cooperative manned space ventures and development of a Chinese space station.

The Chinese have presented potential clients with detailed technical data on their launch vehicles and launch sites. Many of these potential customers did not realize the capacity of the Chinese Space Programme. China is offering to set-up exchange programmes with space-oriented universities or businesses; while at higher levels, their officials are attempting to establish international space protocols.

China's launch site in Gansu Province, northern China has been the base for simultaneous research on the Long March 2 space booster and their 2-ton recoverable satellite. The Chinese geostationary communications satellites and their launch vehicle the Long March 3 were based at Xichang in Sichuan Province. To support these missions, China is expanding its ground and sea tracking and control network (TT&C) and is planning further interconnections via satellite to further enhance capabilities.

The Chinese Academy of Space Technology (CAST) working under the direction of the former Ministry of Astronautics, (now called the Ministry of Aeronautics and Astronautics), has been dedicated to the astronautical sciences and is deeply involved in the Chinese space programme. Included with its membership is the Chinese Society of Astronautics (CSA) which, as China's independent national Society solely devoted to astronautics, fulfills a role similar to that of the British Interplanetary Society (BIS in the UK.

Since 1970, China has launched 23 satellites. They placed their third synchronous communication satellite into orbit in February 1986 and launched a fourth in March this year. In the last four years, they have launched eleven remote sensing satellites and plan to place a meteorological satellite into polar orbit. On the commercial side, they launched and recovered a scientific experiment for Matra in August

1987 as a dual payload on their remote sensing satellite.

China was scheduled to realize additional commercial benefits from its space programme with the launch of their first payload for a US company in 1988. The payload, a Hughes built Wester 6-S owned by Western Union, was to have been placed into orbit using China's Long March 3 booster, but the sale of Western Union to Hughes cancelled the deal. Additional agreements were signed with Sweden for launch of their Mailstar satellite.

The Brazilian Commission on Space Activity (COBASE) has announced that China and Brazil will jointly construct a remote sensing satellite and will launch it by the end of 1992 on a Chinese made launcher. The 1400-kilogram satellites, called China-Brazil Earth Resources Satellite (CBERS), has been in the planning and development stage for two years. It has as its objective a 20 meter resolution from a 800 km orbit altitude.

The Great Wall Industry Corporation has signed an agreement with the Asiasat Consortium based in Hong Kong. A 1.3 ton satellite called Asiasat-1, formerly known as Westar VI, was bought from the Merritt Insurance Corporation. It had been recovered by the space shuttle from an incorrect orbit. Wu Keli, CGWIC vice-president, said the satellite will have 24 transponder slots available for rent to Southeast Asia countries at a cost of $500,000 to $1.5 million. The satellite will be launched on Long March 3 from Xichang late next year.

A top official of the Ministry of Aeronautics and Astronautics announced in May that China intends to launch several urgently needed and operational satellites in the near future for economic development purposes. Satellites for meteorological use, telecommunications, resources and surveying, and marine undertakings are listed as major tasks for China's satellite research and launch endeavours.

Launch Vehicles

China's Great Wall Industry Corporation (GWIC) operating under the reorganised Ministry of Aeronautics and Astronautics offers a series of launch vehicles. To coordinate their efforts in the US, China has appointed Mr. Huang Zuoyi Director, Office of the GWIC Company, to be the launch services director for the US. Mr. Huang was the Chief Engineer for the Wan Yuan Industrial Corporation – the prime contractor for the Long March family of launch vehicles – and also Director of Marketing and Development of GWIC.

China has concentrated on marketing their Long March (Changzheng) expendable launch vehicles. These vehicles have the designation LM in English and CZ in Chinese. At the core of their offer in 1986 were CZ1C, CZ2C, and CZ3 – a three stage launcher using a Chinese developed cryogenic third stage. China claims that these launchers have a combined reliability of about 90 per cent; quite high even by Western standards. (Chinese space activity in 1985-86 was reviewed in ***Spaceflight***, February 1987, p.62).

GWIC plans to build new or modified versions of their core vehicles using a development plan similar to ESA's plans for the expanded Ariane series space booster. Modifications will feature – as with Ariane – stretched stages, improved propellants, and the use of liquid strap-ons as zero stages.

During 1987 GWIC offered new versions of the CZI-series of launchers, the CZ1D and a lengthened version the CZ1M. They are also offering variations of their CZ2-series called the CZ2C-OTM (Orbital Transfer Module) and the CZ2C-MSM (Multi-Satellite Mission). A more capable CZ2 called the CZ2D-PamD will have a geostationary satellite ability.

There are plans for models comparable to ESAs Ariane 3 and 4. These are

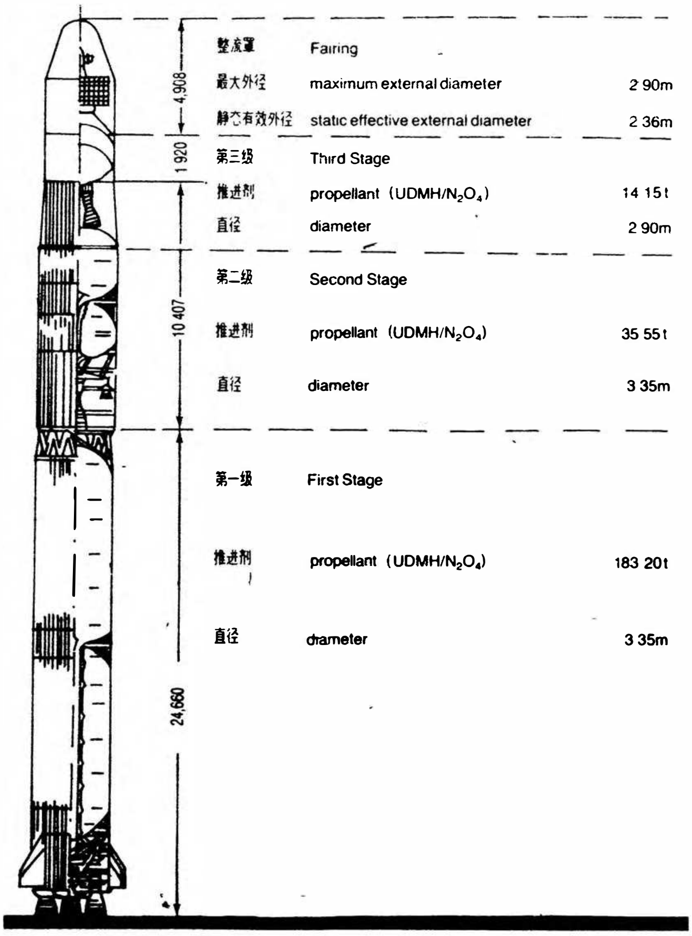
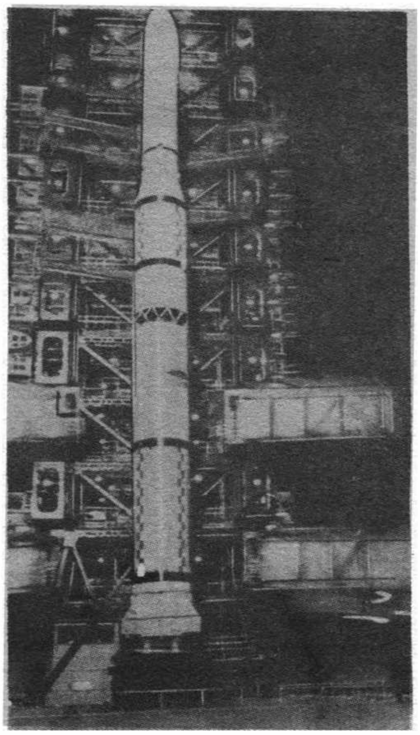


Diagram of the Long March 4.

A Long March 3 on the launch pad at Xichang.



the CZ2E and CZ3-4L – improved core vehicles with four strap-on zero stages. An even larger version of this concept is being considered which will use eight liquid strap-ons; it has a designator of CZ2-8L The Chinese are testing an even more powerful cryogenic third stage which may be used on the CZ3A and will be the core for an improved CZ3A-4L.

A model, shown in Paris at the 1987 Air Show, was an elongated CZ2 with what appeared to be four liquid engines similar in shape and size to ESA's Viking engines. If this configuration is included in Chinese plans for future launchers with heavier capacity, then it might indicate that the Chinese have opted not to develop solid engines and have solved the complex problems that other space transportation developers have had with liquid auxiliary add-ons.

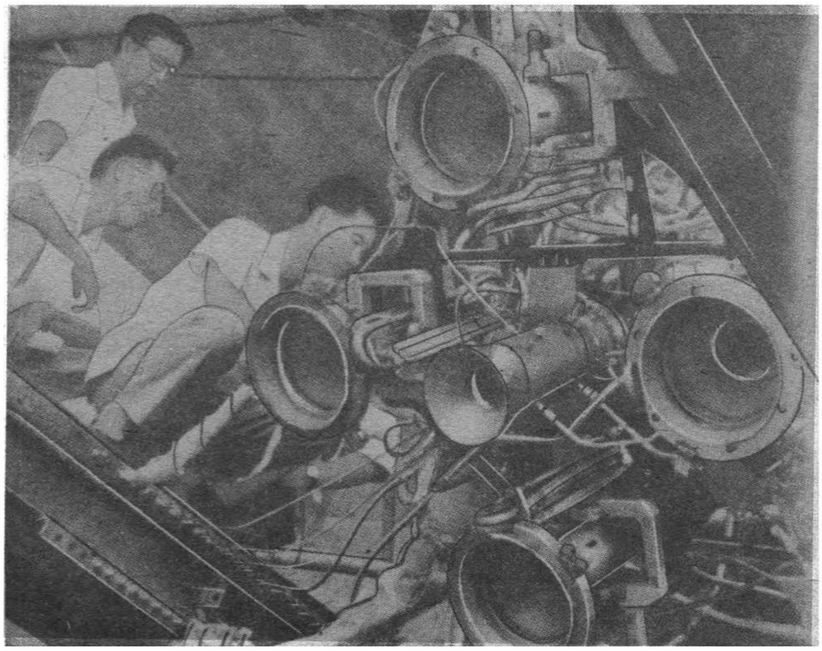
With such a wide range of launchers, China will be able to place satellites into geostationary orbit as heavy as 2,500 kg and up to 13,000 kg into low Earth orbit.

Much of China's success in rocketry can be attributed to the 71 tonne thrust engine which is the basic work-horse of the Long March 3: This engine reportedly has never failed.

The Chinese have used this basic engine in both the first and second stage of the CZ2 and CZ3 as well as the new zero stages of the CZ2-E and CZ3-4L. Western aerospace officials described both the CZ2 and CZ3 as a very efficient design. China runs their engines at about 85 per cent capacity to insure quality control and provide a clear margin of safety. This simplicity considerably improves the overall reliability of the Long March family of launch vehicles.

China has developed at least one new launch vehicle, their new CZ4. The outward appearance of this vehicle is that of a CZ3 with lengthened first and second stages. The vehicle has a conventional propellant third stage – rather than the more powerful cryogenics used in their CZ3 – and a new payload fairing. The vehicle appeared to be at the flight hardware stags and could be available within a year. A paper presented at the IAF conference in October 1987 showed a launcher identified as the CZ4 having only a lengthened first stage. The Peoples Daily on July 2 reported that the "No. 4 Long March rocket, the most powerful in the country's successful series of Long March rockets, will be able to put 2.5 tons into a solar-synchronous orbit" in September 1988.

US and foreign space journals have discussed China's interest in a Saturn 1B-class launch vehicle, and the existence of plans for such a vehicle were mentioned by Chinese officials in 1987. A Saturn-class vehicle is likely to be needed to support their planned space station or for a reuseable space transportation system in the late 1990's.



Checking out 3rd stage engines/CZ-3.

It is significant that, with the exception of CZ2D-PamD, all new vehicle plans use Chinese developed technology, parts and software. Their CZ2D-PamD will require acquisition of a US upper stage or the development of their own. In any event, the CZ2D represents a unique attempt to combine the best elements of Eastern and Western technology while producing a very low cost geostationary launcher.

It is interesting to note that the Australian government has decided to let the AUSSAT system launch two new communications satellites built by Hughes Communications International in 1991 and 1992. In September a choice of launch vehicles will be made between the Chinese Long March, the American Titan-3 and the European Ariane-4. At the present time the Chinese seem to have the inside edge based on cost.

Launch Sites

The first 23 launches have originated from two launch sites. The Jiuquan Space Center, located in Gansu Province, has two CZ2 launch pads and has been in service since 1970 launching scientific and remote sensing satellites.

The second site, called the Xichang Satellite Launch Center, is located in Sichuan Province at the approximate latitude of Cape Kennedy (28-degrees north). Here the Chinese have built a dedicated geostationary launch facility located to take maximum advantage of the rotational momentum of the Earth – resulting in larger payload weight to orbit. A new launch pad for the CZ2-E and the CZ3-4L is being built in an adjoining valley, 1000 meters west of the present launch pad. By adding an extra launch position at Xichang, China will be able to increase its capacity from six to 12 launches per year from the present seven.

Visitors to Xichang observed that even without the new pad, the Chinese have a significant growth potential built into their launch gantry which should see them well into the next decade. However, even with this advanced planning, the Chinese are expanding and improving their satellite handling capabilities for current and future proprietary satellites such as Westar. Plans are in early stages which will increase Xichang's launch vehicle storage and handling capabilities in anticipation of reaching 12 launches a year.

The launch center is a unit of the State Commission of Science and Technology for National Defence and works closely with the newly merged Ministry of Aeronautics and Astronautics.

China may have a third launch site located approximately 60 miles southwest of Beijing in northwest Shanxi Province at about 38.5 degrees North latitude. This site, which may be pictured in a publication called "PLA Forces", resembles the Xichang launch facility and may be used for China's polar orbiting meteorological satellite scheduled for launch within a year. Very little is known outside China about this site. Why the new site is being kept secret is unclear, but this may reflect China's uneasiness with

the commercial world's demand for openness.

Satellite Developments

China's third communications satellite was launched on February 1, 1986. This 3 transponder C-band system was placed at 103-degrees east longitude and called STW-2 (for experimental test satellite). It was put into operation immediately and is using shaped-beam technology unlike their first communications satellite (STW-1) which is using global beams.

A fourth C-band satellite (DFH-2A) was launched on March 7, 1988. It was manoeuvred into synchronous orbit on March 23 at 87.5 degrees east longitude. The Chinese satellite designers have increased the in-orbit power requirements by 50 per cent to cut the required size of the ground antennas in half.

China has filed for three additional C-band slots with the International Frequency Registration Board (IFRB) for satellites called Chinasats 1,2, and 3 – more powerful, 24 transponder systems originally scheduled for launch in 1988 and 1989. China has announced that they have signed an agreement with the German firm MBB to produce radio and television C-band communications satellites called the Dongfanghong 3-series (DFH for East is Red 3). With the Chinasat-series, which may be the same as DFH-3, and their last STW launch in March 1988, China will place at least four new communications satellites into use by 1993.

Premier Li Peng explained to American space experts in Beijing in June 1987 that China feels that C-band will fill all their near-term requirements, but indicated that serving the people's requirements came first and left open the expansion into Ku-band if needed in the future. He indicated that China wants to sell comsats, metsats, remote sensing satellites as well as services, while expanding their entrée into the world's space markets.

Right now, China can annually produce and launch eight to ten satellites, while their actual launch rate has been one to two satellites per year.

There have been eleven remote sensing satellites launched and successfully recovered since 1974 and all have successfully returned film data. Real-time imagery from combined CCD and television camera systems have been carried on these satellites since 1983. The more recent remote sensing satellites have produced images with 19-meter resolution – exceeding that for the TM system on Landsat.

The French firm Matra became China's first commercial space customer in August 1987 when a Chinese rocket carried a microgravity experiment into space. The experiment was successfully returned to Earth after five days in orbit.

This was the ninth successful recovery without a failure since 1974. The tenth launch and recovery was conducted in September 1987 of a new scientific satellite which remained in orbit for eight days. China carried out significant experiments in material processing by obtaining torch-shaped gallium arsenide monocrystals of greatly improved purity.

In July of this year, West Germany used China's retrievable satellite to conduct two research projects under weightless conditions. The experiment module carried two sets of West German equipment, one for monitoring and recording the external conditions during the flight, and the other for conducting experiments in the growth of protein crystals.

Up to now about 10 companies from the US, Australia, West Germany, Switzerland and France have asked to rent space on the recoverable satellites.

At present, China is the only space authority, outside of the Soviet Union, able to offer a satellite recovery service. Additional experiments are planned with Matra and other countries have asked about this unique capability. Returning packages from space may be an area where China finds no competition as the US and the USSR are not offering this as a commercial possibility. ESA also lacks the capability.

China has two kinds of recoverable satellites for commercial offering, called FSW-1 and FSW-2 (for FAN SHOU

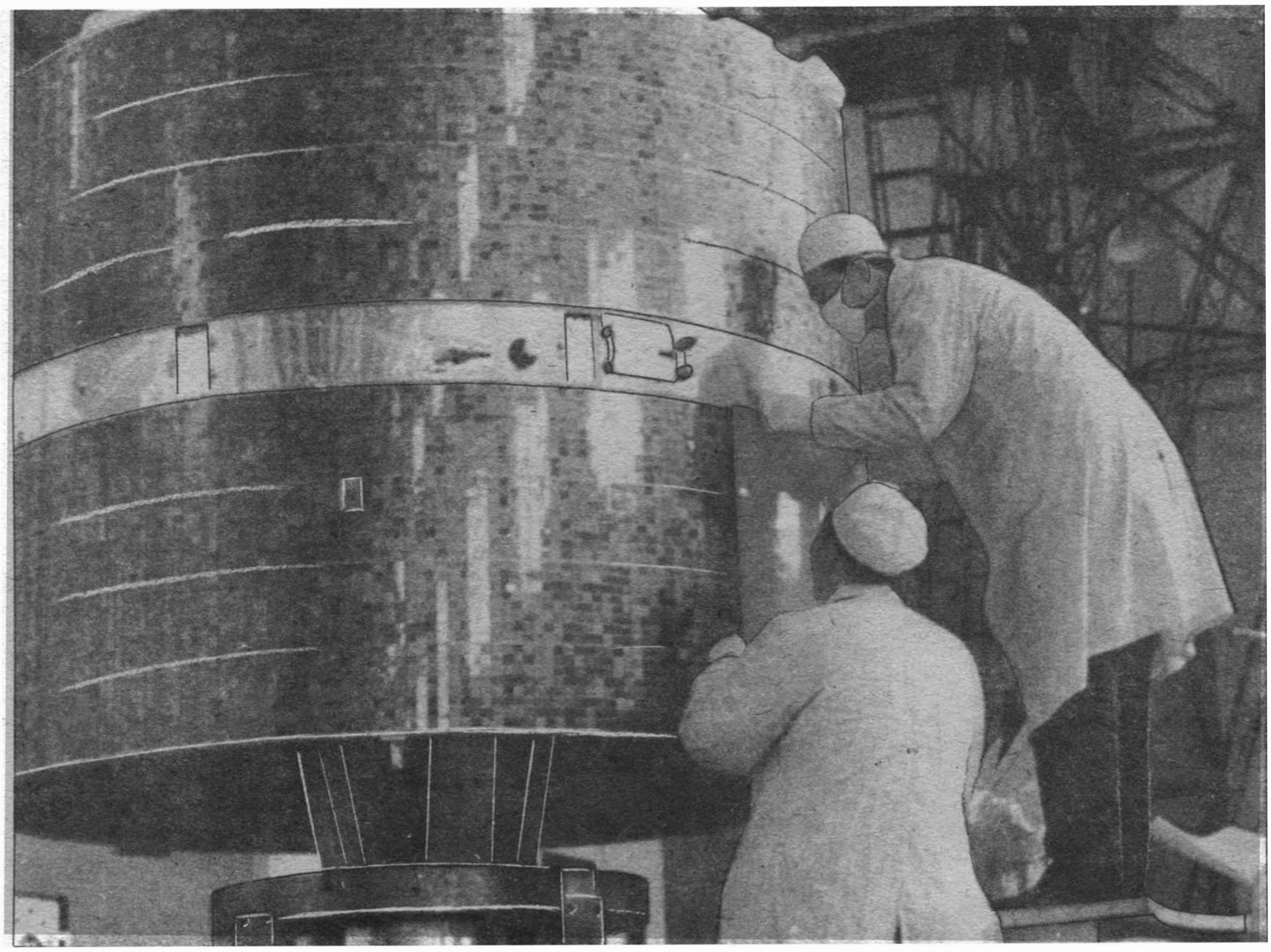
A recoverable satellite is surrounded by crowds of on-lookers soon after landing

Chinese Recoverable Satellites

	FSW-1	FSW-2
Dedicated Satellite (1)		
Recoverable Payload	150 KG	200-300 KG
Non-recoverable	150 Kg	300 KG
Industrial Co-passenger (2)		
Recoverable Payload	20 KG	150 KG
	2-10 KG packages	15-20 KG packages
Power	27 V, 100 W	27 VDC
Operational Parameters		
Altitude	175-400 KM	175-400 KM
Inclination	57-70 degrees	57-70 degrees
Period	90 minutes	90 minutes
Duration	5-8 days	10-15 days

(1) Completely dedicated satellite
(2) Available space on current satellites-limited size. Fits get-away special.

CHINA



Chinese technicians install solar panels on the STW-1 satellite.

WEIXIAN or recoverable). Launched from Jiuquan on CZ2s both are de-orbited by commands from Xian and landed in the Sichuan Basin.

China plans to launch a polar orbiting meteorological satellite soon. The satellite (Fengyun No.1) weighs about 750 kg and will be placed into a 900 km sun-synchronous orbit. With a planned lifetime of one year this will be the first of a series of satellites which China feels will be necessary for the proper development of their economy and natural resources. The Chinese have also shown a mock-up of a 1,200 kg geosynchronous meteorological satellite, due to be launched after 1990, which is expected to have a lifetime of four years.

The Chinese plan to launch a more capable Landsat-type system with a 10-meter resolution later in the 1990's. China installed a sophisticated Landsat receiving site northeast of Beijing in 1986. It is now capable of receiving Landsat and Spot signals and possibly their own. Future plans call for an additional Landsat station to be built in west China because the present site cannot receive imagery of all China. With two locations, China will have complete coverage of the country.

Reflecting their new direction and openness, the Chinese have shown a navigational satellite – as yet unlaunched – plans for a geostationary metsat system, advanced communications and astronomical satellites. Each of these will be launched as China's overall requirements dictate.

It is clear that China's satellite manufacturing capability, although not large, is very good and is being offered to the under-developed countries. China's ability to build complete, complex space systems has already been demonstrated. The reliability of China's satellites has been high, none having failed in orbit. Add to these items the fact that China's investment cost is much less than comparable foreign systems and you have the makings of an active competitor for commercial space.

Wu Keli, CWGIC vice-president has said, among other things, that Chinese quoted prices for launch services are generally lower than launching prices of European countries and the US because labour force expenses in China are lower. He stated that the CGWIC does not "receive great subsidies from the government" and does not "dump at low prices". He said that CGWIC is solely responsible for their profits and losses and instead of subsidies, CGWIC pays state taxes, and also provides meals for all of its workers and staff members. Mr. Keli pointed out that, like Ariane and the US, when a new launcher enters the international market, the first two or three launchings are offered at low introductory prices and then launching services are provided at normal prices.

Environmental Testing

China has developed most of their domestic environmental test equipment, simulating mechanical, thermal, vacuum, high energy radiation, acoustic and electromagnetic environments.

The Environmental Simulation Center of the Chinese Academy of Science and Technology has 7-meter diameter and 12-meter high test chambers capable of extremely low torr values. These chambers are fitted with heat sink cooling and thermal radiators. A new sophisticated vacuum

chamber was installed in 1986 especially for large component testing of their metsat.

The Chinese laboratories have large-sized centrifuges and shaker-tables which are capable of random or sinusoidal vibration test of whole satellites. Mechanical analysis of satellite structures is supported by model analysers and similar complex test equipment. Chinese computer assisted design techniques are improving just as quickly as they can develop the technology.

Supporting Network

The Chinese have a well developed supporting space network. China's space factories, institutes, scientists and space engineers have an enormous capacity. A similar capability was observed at rocket engine test facilities, satellite design factories and launch sites. The Wan Yuan Corporation, China's main rocket production plant in southwest Beijing reportedly could build from seven to ten rockets per year, but were producing orders only as needed. A similar plant in Shanghai could produce an additional five to six vehicles but it also was working only by special order. With this combined capability of producing up to 16 space launch vehicles per year and a limited national launch schedule of two or three launches per year, China easily could provide 10-12 commercial launches within the next few years.

China's TT&C Network

The Chinese TT&C network is basically a land-locked system supported by three TT&C ships. The heart of the network is located at the Xian Satellite Control Center where China has installed their equivalent of the Johnson Space Flight Center. This facility now has the capability to control delicate orbital manoeuvres of complex geostationary satellites launched from Xichang as well as the capability for deorbiting satellites launched from Jiuquan for recovery in the Sichuan Basin. A back-up center for geostationary missions is located at Shaxian in Fujian province and Chinese officials are considering locations for foreign tracking sites.

Additional tracking facilities are located peripherally around the Chinese landmass. The original tracking system depended heavily on optical tracking and interferometric devices. Today's locations use laser tracking, Chinese made high precision optical devices, Doppler radars and short baseline interferometers.

To increase their ability to support commercial launches, China placed its tracking ships in dry dock in 1987 to undergo extensive modifications including the addition of Intelsat antennas. In order to provide a direct link to the US for Western Union's benefit, a new communications system was installed at both Xian and at the Xichang Launch Control Center. Each of these changes reflect China's willingness to service customer needs while insuring mission success.

In May 1988, the ocean going survey ship "Yuan Wang" which belongs to the National Defence Science, Technology and Industry Commission was added to service as a ship-based satellite station. This has many complementary capabilities for space tracking and can transmit telephone calls, telegrams and receive TV broadcasts.

International Developments

China's entry into the space launch services arena represents in part an attempt to generate hard currency for the PRC. The most important benefit will be to the Chinese space industry which needs to increase the rate of space launches.

China's ability to provide low cost launches with a reasonable delivery date and a ready national insurance programme will probably siphon-off some clients which cannot find room on the dormant US programme or overbooked ESA services. The Soviet offers of launch services probably will not disturb the Chinese programme much. The Chinese market share will depend largely on early successful launches.

China is also in a position to provide meteorological and remote sensing data and communications satellites to under-developed countries, multiplying their economic leverage while increasing their international prestige.

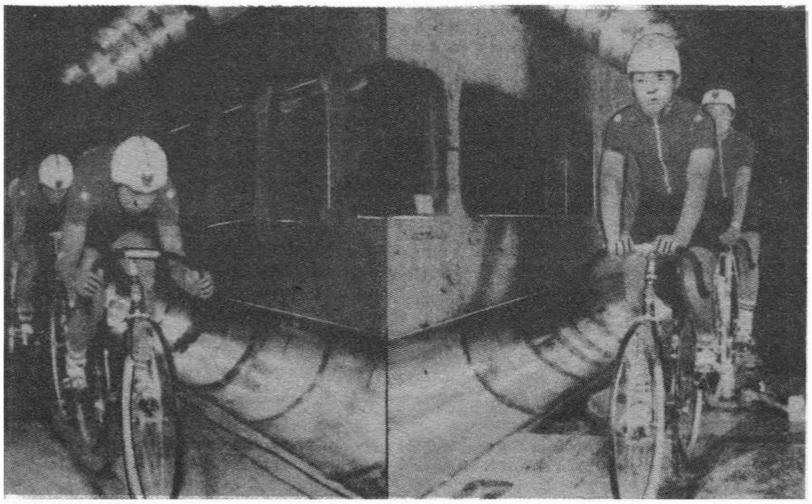
Future Expectations

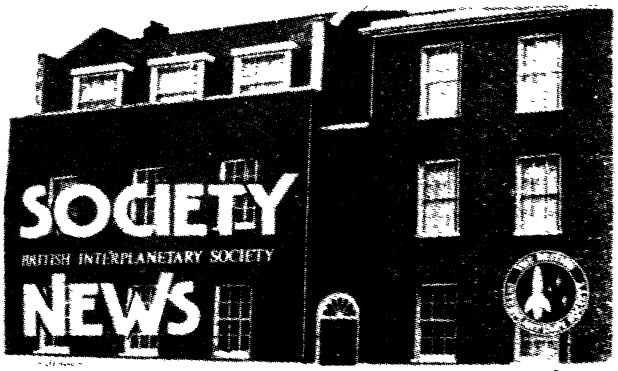
China will continue to develop new launch vehicles with increased thrust capabilities necessary to support future manned and unmanned programmes. The carrying capacity of the Long March rockets will rise from the present 1.4 tons to 4.5 tons for stationary orbits and from 4 tons to 9 tons in LEO. However the lack of funds and the incomplete nature of the Chinese legal system may slow the development of China's space industry.

There will be new satellites developed for China and its customers. China has revealed plans to build its own space station. Discussions have been underway considering the construction of a Chinese module for the US space station. Either of these efforts will require Chinese development of a manned space capability. Newspaper reports suggest that this is just what China is doing by establishing a new, modern training facility for future astronauts in a western suburb of Beijing. This walled facility has apparatus that is every bit as good as any western or Soviet astronaut training center. For example the largest centrifuge for human experiments in the world is there with a rotary arm of 30 meters in length and 9 meters in height.

China sent eight of their most promising graduate level space engineers and scientists to the new International Space University whose inaugural programme began at MIT in June 1988. One of those graduating in August was a management level scientist from the Beijing Space Flight Medicine Programme Research Center who is upgrading his skills. The Chinese are clearly laying the groundwork for a significant Chinese presence in space for the future.

Chinese astronauts, seen here during training





New Support for Member Services

The Society has acquired computer and ancillary equipment, including software, to facilitate the administration of member services. The equipment acquired includes an Epson PC AX 40 MB, an Amstrad PC 1640 twin floppy, Irwin 40 MB tape backup unit plus networking hardware and software and a Brother 1709 printer. All membership records and accounts are currently being transferred to this new base.

The software has been specially developed for the Society to handle its membership records and will be able to accommodate direct debits and subscription information. The new database should be ready in November and extensions to incorporate other items, particularly accounting records, are planned to follow later along with studies on the feasibility of creating a Library database as well.

Annual Subscriptions

Annual subsrciptions are due on or before January 1, 1989. Prompt payment is more than ever necessary this year owing to the introduction of the computerised dispatch system which will automatically omit sending magazines to members who are late in settlement and will not reinstate dispatch arrangements until payment is recorded.

The effect of this will undoubtedly be that the 1989 issues will run the risk of arriving late, unless special effort is made to remit in good time.

Members with UK bank accounts are urged to complete Direct Debit forms, obtainable from the Society on request. These will avoid all difficulties of this nature and ensure that the dispatch of magazines is not interrupted.

News . . . Society News . . . Society

A Society Archive Collection

The Council has agreed that the Society should hold a representative collection of space artifacts, particularly those which relate to its own involvement in space matters, and to retain them for posterity in the form of Society Archives.

The last AGM approved a change to the Society's Constitution to pave the way for collecting and preserving such material. This was followed by a Council Bye-Law which set out how the work should be undertaken and monitored, the Executive Committee being charged with the task of designating the first areas of interest

The Council's Bye-law reads as follows:-

"Subject to Article 60 and Bye-Law 31 (h) which charge the Executive Secretary with responsibility for building up and maintaining in proper condition Society Library and Archival collections, the Council may

(a) designate books, artifacts, works of art and other items, henceforth referred to as "The Collection", as items of special interest
(b) The Collection shall be established and maintained for historical record and exhibit purposes and shall relate to the concept of the exploration of space and to such matters or events in which the Society has been associated or be deemed to have an interest, for any reason or purpose.
(c) The Executive Secretary shall be authorised to receive and disburse funds secured for such purposes, subject to Council directives, and to maintain a proper record of each acquisition.
(d) The responsibility for designating items forming the Collection shall be delegated to the Executive Committee and items so designated shall thereafter be subject to the provisions of clause (e)
(e) No part of the Collection may subsequently be sold or otherwise disposed of without the authority of a Special Resolution approved by ballot from among all the Fellows of the Society "

With these preliminaries underway, the Library Committee has begun to consider what exhibit arrangements should mark the Society's upcoming 60th Anniversary and how these may be accomplished.

The work involved is substantial Early steps will consider the development of a computer programme able to provide the historical data and references necessary, as well as deciding on a layout of suitable exhibits likely to give pleasing results.

Comet Engravings

The Society has been fortunate in acquiring some of the beautiful engravings from Stanislai de Lubienietski's *Theat-*

MEETINGS DIARY

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE. Subject to space being available members may also apply for a ticket for one guest.

2 November 1988, 7-8.30 p.m. **Lecture**

UK INVOLVEMENT IN SATELLITE NAVIGATION

Dr. I.L. Jones (*British National Space Centre*)

Members and their guests only. Please apply for admission tickets in good time enclosing SAE.

15 November 1988, 10-4.30 p.m. **Symposium**

EXTENDING THE SPACE INFRASTRUCTURE

The reports of the National Commission on Space and Dr. Sally Ride have paved the way for a new innovative space policy in the United States. It encompasses the setting up of bases on the Moon and manned exploration of the planet Mars. The purpose of the symposium is to encourage and review American proposals and possible European contributions.

The symposium covers the following subjects:
- Infrastructure planning
- Orbital transfer systems
- Geostationary operations
- Lunar transportation system
- Lunar bases
- Planetary exploration systems
- Exploitation of the solar system.

Offers of Papers are invited
Authors wishing to present papers should contact the Executive Secretary.

Registration
Forms and other details are available from the Society. Please enclose SAE.

Please note the venue of this meeting has been changed to Millbank Tower, Millbank, London SW1P 4QU.

30 November 1988, 6.30-8.30 p.m. **Visit**

SCIENCE MUSEUM

A special visit of Society members to the Science Museum in South Kensington. The programme will provide an opportunity for a leisurely view of the Space Gallery and to see vintage space film footage.

The fee will be £6 00 per member to cover the cost of a buffet with wine which will be provided.

Advanced registration is necessary as the party will be limited in number. Guests will be allowed if space is available. Forms are available from the Executive Secretary.

LIBRARY

The Society Library is closed until further notice.

Peter Conchie

We offer congratulations to two long-standing Fellows of the Society who received honours in the Birthday Honours List. The CBE was awarded to Patrick Moore for services to astronomy and the OBE to Peter Conchie, Business Manager in the Space and Communications Division of British Aerospace.

Among Patrick Moore's many contributions to Society activities was that of editing ***Spaceflight*** during its early days following its first publication in 1956. For many years, Peter Conchie served on the Society's Council and actively participated in the Society's programmes in Space Technology and Space Education.

Patrick Moore

rum Cometicum, which appeared in 1681 and which was one of the most extensive medieval treatises on comets ever produced.

The comet first appeared in 1664, became invisible during perihelion at the end of that year and reappeared early in 1665, thus giving rise to the belief that there were two separate objects. However, the dual appearances caused Borelli, in 1665, to express the opinion that its path was parabolic, a completely novel concept at the time.

The comet of 1664 is of particular interest because it was contemporary with the Great Plague which decimated the population of London.

Indeed, for generations afterwards, the Comet of 1664 was regarded throughout England as the harbinger of that terrible pestilence.

John H. Disher

Pioneer in Manned Space Flight

We regret to record the death of John Howard Disher (Fellow), a retired member of the NASA Senior Executive Service who served as the first Project Director for the Apollo Lunar Landing Program.

John received a degree in Mechanical Engineering in 1943 from the University of North Dakota and later performed graduate work at the Harvard Business School. He began his professional career at the NACA Lewis Research Center, Cleveland, Ohio where he was expert in aircraft propulsion and aero-thermodynamics. Shortly after the launch of Sputnik in 1958 John came to Washington DC as part of the nucleus of experts who were assembled to establish NASA, and to plan the initial US space effort. He helped to establish the Mercury and Gemini Manned Space Flight Programs and headed initial studies of the Apollo concept which resulted in the programme that brought about the successful manned lunar landing in 1969.

After Apollo, John became Deputy Director of the Skylab Space Station Program from its inception to successful completion. He then continued to evolve new space programmes such as the International Tether Program, the Manned Maneuvering Unit used so successfully on the Space Shuttle and many of the basic concepts now being incorporated in the US Space Station. Since retirement from NASA in 1980, he has acted as a technical and management consultant, helping with the organisation and management procedures for the new Italian Space Agency.

Mr. Disher received numerous awards, these include co-recipient of the Collier Trophy for Skylab; the NASA Distinguished Service Medal; two NASA Exceptional Service Medals, and the University of North Dakota SIOUX Award for outstanding career achievements. International recognition includes membership in the International Academy of Astronautics, Fellowship in the British Interplanetary Society and Associate Fellow of the A.I.A.A.

43rd Annual General Meeting

The formal business of the Society was dealt with expeditiously by members attending the 43rd Annual General Meeting, held in the Society's Library instead of its Conference Room as a result of the current extensive renovation of the Society's premises.

After an opening Report by the President on the Society's activities during 1987 and approval of its Accounts for that year, the appointment of our new Auditors was confirmed.

A change to the Society's Constitution was then tabled which gave the right to Fellows of the Society to insure over the years, that no part of the Society's proposed Archival Collections should be sold or otherwise disposed of without their prior consent. This proposal met with satisfaction and was passed unanimously.

Owing to the resignation of Mr. C.R. Hume, who had been prevented from continuing on the Council by other commitments, a total of five Council vacancies were to be filled. The President noted that five nominations had been made and, with the approval of the Meeting, proposed that these be accepted and voted upon *en bloc*. This was agreed unanimously and the five nominees thus confirmed in Office were Mr. G.W. Childs, Dr. R.D. Gould (previously a co-opted Member), Dr. R.W. Holdaway (a new Council Member), Dr. L.R. Shepherd and Mr. G.M. Webb.

The general discussion which followed ranged over a wide field embracing arrangements for holding specialised meetings of the Society, particularly in view of the proposed extension to its premises, and comment on the UK Government's Space Policy. On Society matters the reply was given that most of the work currently under way concerned No. 29 i.e. our Grade II Listed Building, which had to be conducted with some care and in close consultation with English Heritage as it seems to be the only building of its type left in London. Work envisaged to improve and update our HQ premises had been provisionally allocated to four phases, the first of which was currently underway. Phase 2, concerned with improvements to the entrance and corridor was scheduled for 1989. Phase 3 was the proposed extension for which funds were currently being sought. If all goes well, it was hoped to make a start on this in 1990. Phase 4 was a matter of improving administrative facilities and was still some years off.

The meeting concluded with a Vote of Thanks from the floor to acknowledge the work of the Society's staff in maintaining its full range of activities throughout the year, in spite of much inconvenience, coupled with further thanks for the excellent work accomplished both at the Brighton Congress and at Space '87.

* * *

CORRESPONDENCE

UK Space Policy

A Space Reconciliation

Sir, In recent months the level of government support for space has been the subject of fierce controversy. There are many demands on the public purse. The space industry has been asked to justify claims that money spent on space would be better spent than for example, on additional medical research. Media attention has tended to focus on individual, confrontational statements, usually implying that the government are technical Phillistines for not automatically realising the necessity for increasing the space budget. Behind the scenes there has been a greater degree of common ground between industry and government and much done to build on this, rather than engage in more public but less constructive disagreements.

The present government is committed both to fiscal realism and a Britain at the forefront of technology. This means that industry looking to spend public money has to be able to convince the government that it will lead to benefits that can be shown to help the ordinary citizen, e.g. by creating jobs, and that the investment will be of a seed-corn nature, leading eventually to a free-standing industry. It is no good bolstering an industry if this leads simply to a demand for even more cash next year. It is also necessary to show that government investment will lead to achieving these aims more quickly, or in more areas, than relying on private investment alone.

Space has had difficulty meeting these criteria in the past. Benefits have sometimes intended to be couched in our own terms (e.g. it is worth doing this because it will enable us to launch a bigger mass) rather than in man-in-the-street values. At the other extreme we have sometimes emphasised spurious advantages, e.g. the 'non-stick frypan' arguments.

In addition, because governments have financed spacecraft and hence received data free, some of the profit from space has been hidden - for example, the true value of meterological data which is used free by the media.

To convince the government of the value of space it is necessary to explain a number of things more fully.

Firstly, it is important to define different types of space projects and the different stages that the various technologies have gone through. For example, telecommunications satellites are now a free-standing business and it is likely that the same will happen to Earth resources in due course. In this way the public can see that each technology moves from investment to a free-standing business, rather than contemplating the expenditure as a continuing drain on resources.

We also should not underrate the value of pure scientific missions and the effect they have on the public imagination. We need to improve our ability to show these as worthwhile additions to human exploration, rather than as obscure and irrelevant research.

Projects such as Columbus are best represented as the same sort of basic but unglamourous facilities as, say, roads or telephone lines. The government may have built the M4, but we all gain through the massive private investment from new industries that have sprung up around it.

Space breeds enthusiastic workers. This is important but it is equally important that they temper commendable zeal with an acceptance that good government will always require them to justify what they want to do with public money in terms of benefit to the people who contributed it.

We have all complained when we have seen a government spending money on what we see as a pointless extravagance, so we cannot but accept that others may feel like that about space.

European governments are also asking more questions about their space budgets but, in the end, space will be the stronger for that.

P. CUTCHER
Manager, Space and Avionics Division
Mait Limited Winchester
Hants, England

Effects of UK Space Policy on ESA Recruitment

Sir, My earlier letter drew attention to the current non-recruitment of UK citizens to ESTEC, the technical laboratory of ESA and its single largest facility.

I have since updated the recruitment data to August 15, 1988, commencing at November 1, 1987, as before. The figures are even more disturbing viz:

France	54	Norway	6	The Netherlands	1
Italy	27	Sweden	6	Denmark	1
Germany	21	Austria	6	Eire	1
Belgium	9	Canada	5		
Spain	8	Switzerland	3	Total	148
				UK	0

During the same period, 7 UK and 49 non-UK personnel left, giving a net increase in the period of 92, none of whom are from the UK. The degree of UK participation in ESA at ESTEC is therefore diminishing rapidly.

I have also been analysing data on participation in the third European Symposium on 'Space Thermal Control & Life Support Systems' held at ESTEC in October, a prestigious event for Europe, with additional involvement from the USA, the USSR and Japan.

'Space Thermal Control' is a basic discipline affecting the design, configuration and operation of every spacecraft, manned or unmanned. Since the UK has apparently abandoned any interest in manned programmes, one could not expect to see much UK participation in the 'Life Support Systems' side of the Symposium, but what is really alarming is to note the very low involvement in basic 'Space Thermal Control'.

Out of the 84 papers to be presented, only 4 originate in the UK. As might now be expected, Germany, France, Italy and the Netherlands contribute the greatest proportion, (57), the remaining 23 coming from the USA and Belgium (4 each), Austria, Japan and ESA (3 each), the USSR and Spain (2 each) and Denmark and Switzerland (1 each). Naturally, the small numbers from the USA, the USSR and Japan, reflect their limited participation in what is basically a European Symposium but the small number from the UK must reflect another factor.

The Organising Committee of the Symposium has representatives from Germany, France, Italy, the Netherlands, the USA and Japan. The only UK-related person is one of the six ESA experts. Similarly, of the 27 Session Chairmen, apart from eight ESA personnel from different countries, and 18 representatives directly from other countries (seven from Germany alone!) there is a sole UK representative.

The same lamentable conclusions, seemingly, can be drawn from all these statistics as from those in my previous letter. Viewed from the international standpoint, and even from the more restricted European one, the UK now hardly counts as a spacefaring nation, in spite of such a promising start in the 1960's, and in spite also of the heroic efforts of the BIS.

One can only wonder how, and even if, this trend can now be reversed.

D.H. HOWLE
Yeovil, UK

Apollo 11 EVA

Sir, Please allow me to congratulate Mr Arnold on his excellent detective work in identifying the sole Hasselblad photograph of Neil Armstrong taken on the lunar surface (***Spaceflight***, July 1988, p.284). After nineteen years of viewing the several "classic" photos of that historic mission, seeing the Armstrong photo breathes new life into Apollo 11's EVA.

If I may be so bold to suggest, I think it would be fitting to present Neil Armstrong with a framed enlargement of the newly identified image. What better way to commemorate the upcoming twentieth anniversary of his historic moonwalk?

T.J. FRIELING
Campaign for Space
Georgia, USA

Apollo Videotape Lost?

Sir, A few years back, I inquired at NASA regarding the availability of the videotapes of the Apollo lunar surface TV transmissions. The shocking response I received was that, but for a few hours from the Apollo 16 mission, they no longer exist!

Numerous inquiries elsewhere turned up only kinescopes, but these are much inferior to the quality of the original videotapes from which they were made. (Graininess, reciprocity failure, dye stability, accessibility, etc. make 16mm film a very poor archival medium for such an historic treasure).

With scores of hours of sometimes spectacular TV coverage this loss (?) of the original video would, I believe, make the regrettable "missing picture" of Neil Armstrong (***Spaceflight***, July 1988, p.284) seem pale by comparison. Perhaps some of ***Spaceflight's*** readers can provide information on whether any direct video still exists elsewhere.

RICHARD KOZAK
Flagstaff, Arizona, USA

Ed.- *An inquiry to the Johnson Space Center concerning the availability of Apollo TV transmissions brought the following response:*

"Video downlinks are on film at the Johnson Space Center. There is evidently some question as to the shelf life of video tape as opposed to film. According to the Public Affairs Office at the Johnson Space Center the purchaser will have to pay for conversion of the film to video tape. Additionally these films may be viewed at JSC."

Number of People in Orbit

Sir, Like Yaron Sheffer (***Spaceflight***, August 1988, p.331) I have kept a record of everyone who has been into space, or, more precisely, into orbit. (If the X-15 pilots, some of whom are considered by some people to have made sub-orbital flights, are excluded, the number is the same, because everyone who made sub-orbital flights also made orbital ones). The number stands at 206 up to and including Anatoli Solovyev and Alexander Alexandrov of Soyuz TM-5. Readers may be interested in some of the traps for the unwary when counting people in orbit.

In at least one case differing transliterations of Russian names caused an error, when a list included both Aksenov and Aksyonov, who are, of course, the same person. He flew on Soyuz 22 and T-2.

Similarity of names has also caused confusion at least once, when Anatoli Berezovoi flew on Soyuz T-5 and some of the media identified him as George Beregovoi of Soyuz 3. This just goes to show how little checking the media do, since even the minimum research would have shown that Beregovoi was, at 47, the oldest person to go into space up to that time, and was 61 at the time of Soyuz T-5.

With regard to identical surnames, I think the following list is complete:

There have been two Titovs, Gherman (Vostok 2) and Vladimir (Soyuz T-8 and TM-4); two Volkovs, Vladislav (Soyuz 7 and 11) and Alexander (T-14)- two Gibsons, Edward (Skylab 4) and Robert "Hoot" (SM 10 and SM 24) - and "Hoot" Gibson's wife, Rhea Seddon, has also been into space (SM 16); two Walkers, Charles (SM 12, 16 and 23) and David (SM 14); two Fishers, Anna (SM 14) and her husband William (SM 20); two Nelsons, George "Pinky" (SM 11 and 24) and Bill, the Florida Representative who also flew on SM 24, making it the first (and so far only) flight to carry two persons with the same surname; and two Solovyevs, Vladimir (Soyuz T-10 and T-15) and Anatoli (TM-5).

But it is the Soyuz TM-5 flight which has the greatest potential for confusion, since it means there have been two people in space with exactly the same name, Alexander Alexandrov! The first, a Soviet, flew on Soyuz T-9 and TM-3. The second, a Bulgarian, was the backup for the first Bulgarian cosmonaut, Georgi Ivanov (Soyuz 33), before getting a flight himself on TM-5.

As Yaron Sheffer says, Alexander Laveikin (Soyuz TM-2, February 1987) was the 200th person in space. (The distinction would have gone jointly to Mike Smith, Gregory Jarvis and Christa McAuliffe of SM 25 if not for the Challenger disaster). The 100th was Victor Savinykh (Soyuz T-4, March 1981) - he was also the 50th Soviet cosmonaut to go into space. It is interesting to note that from the 1st person in space (Gagarin, Vostok 1, April 1961) to the 100th took nearly 20 years, while from the 100th to the 200th took less than 6 years - and would have taken less than five but for the Challenger tragedy. There have been only six more up to the time of writing in the one-and-a-half years since the 200th, which shows clearly the effect of the stopping of Shuttle flights since the Challenger explosion.

Compilers of lists of space travellers ought to stop calling the Hispanic spacemen, Arnaldo Tamayo Mendez of Cuba (Soyuz 38) and Rodolfo Neri Vela of Mexico (SM 23), Mendez and Vela, and listing them under M and V?

In the Spanish-speaking world a person's last name is the mother's family name. It is, however, the father's family name, placed next to last which is (as in the English-speaking world) regarded as *the* surname, by which people are known and under which they are entered alphabetically. So the Cuban should be called Tamayo, or Tamayo Mendez, but not Mendez, and entered under T, and the Mexican Neri, or Neri Vela, but not Vela, and entered under N. (Note that the mission patch for his flight said Neri, not Vela.) Similarly, Tamayo Mendez's backup, José Armando Lopez Falcon, should be called Lopez, or Lopez Falcon, but not Falcon.

Gordon Hooper gets these names right, but alas adds a hyphen (Tamayo-Mendez, Lopez-Falcon). The only other Hispanic spaceman, Franklin Chang-Diaz, a Costa Rican who became a naturalised US citizen and flew on SM 24, seems to have adopted a hyphen himself, and since that was his own choice it should of course be used. At least it removes confusion!

RAY WARD
Sheffield, England

CORRESPONDENCE

Energia Motors

Motors shown on the current Soviet model of Energia may not necessarily be the same as those actually used on a full scale Energia launcher, *writes A.T. Lawton.*

Sir, A very handsome model of the Soviet's new Energia launcher was displayed at Brighton during Space '87 and more recently at Space Commerce '88 in Montreux. It was shown on the front cover and on page 15 of the January issue of ***Spaceflight*** but has already raised doubt with regard to its accuracy. Peter Bond [1] commented on the discrepancies in the model compared with the actual figures given by technical data displayed alongside and emphasises a particular discrepancy, namely the official height of the launcher compared with the unofficial scaled height of the launcher as derived from the model. This matter was raised again by Tony Devereux [2] and by Mike Salmon [3].

I had the opportunity to examine and discuss with stand officials the Energia model and the central core motors in particular. I agree with Mr Devereux's comments that it provided "enough information to produce a plausible model without being technically exact".

The motors on the core appear to be intended for steering the whole complex, an excellent system – for the whole servo steering system remains with the launcher throughout its flight. In contrast, the nozzles of the SL-16 type boosters are fixed although they are probably steerable on the SL-16 itself.

However, the method of steering shown on the Energia model places extreme demands on seals, both in terms of bearing load and gas temperature and pressures. The seal implications are shown in Fig. 1. The nozzle is free to move in any direction and can be easily steered by two servo motors in elevation and azimuth. The spherical shape of the combustion chamber is interesting for it has two advantages:

1. The spherical shape presents a constant frictional force whatever the direction of movement.
2. A spherical surface offers the maximum stress withstanding capability for a given volume and mass.

It is therefore interesting but not technically convincing.

The nozzle of the motors on the model are also difficult to conceive as working over the expansion ratios required for working from ground level to LEO (low-Earth orbit).

In short I would suggest that the core motors shown on the Energia model may *not* represent those on the real full scale item.

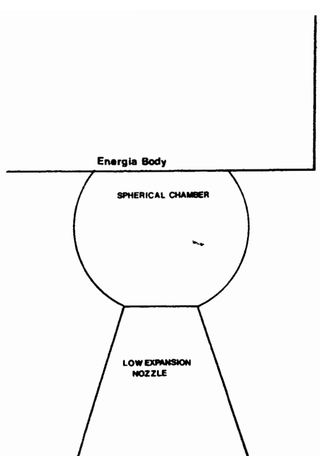


Fig. 1. The motor of stage 2 as shown on the Energia model at Space '87 (not to scale). ©Lawton

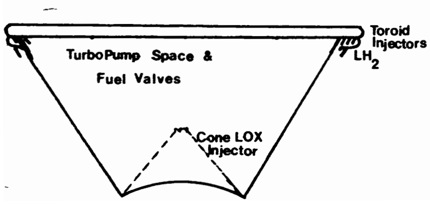


Fig. 2. Schematic of 200 tonne thrust LOX LH_2 Plug or Aerospike Motor as might be fitted to the core of Energia. Diameter: 3.3m; Length: 1 13 m; Weight (dry): 1450 kg; Flow Rate: 400 kg/sec.

I would suggest the best design rests on the so called plug nozzle or Aerospike concept originated in the West by Rocketdyne in 1974 [5 & 6].

The motor that would derive from the system is shown in Fig. 2.

It will be noted that four 200 tonne motors of such outline could easily be incorporated in the 8 m diameter core stage of Energia shown in Fig. 3, with room for guiding and deflector skirts which bear a resemblance to conventional bell mouth nozzles.

It will also be noted that a 200 tonne thrust 'aerospike' nozzle is 1.13 m (3ft 8½ ins) long compared with an approximate 5.3 m (17 ft 5 in) of the conventional bell mouth. This very conveniently answers the points raised in Refs 1,2.

All photographs of Energia so far released have screened the motor bay, so it cannot be proved that Energia *does* use aerospike engines.

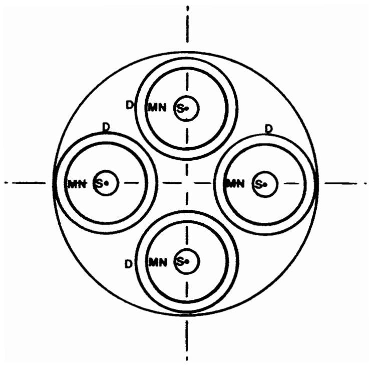


Fig. 3. Showing how four 200 tonne thrust LOX LH_2 motors could be incorporated into the 8 m diameter core stage of Energia. (Scale 1 cm = 1 m) Key: S – Motor Spike; MN – Motor Nozzle; D – Deflector Shield. ©Lawton

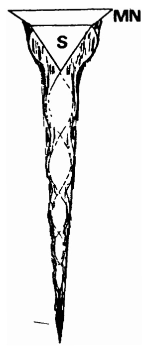


Fig. 4. Flame shape of Rocketdyne Aerospike Motor at sea level (from Ref.6), with acknowledgements to the AIAA

A final possible clue is the shape of the exhaust flame at lift-off. The Rocketdyne motor at sea level has a flame shape shown in Fig. 4. This is close to the flame shape of the central core emission.

Until more technical detail of the *real* Energia engine assembly is shown the above remains conjecture. If the Soviets *are* using plug or aerospike motors it would account for the high performance and stretch capability expected of the Energia.

A.T. LAWTON
Goring, Sussex, UK

Reference

1 Bond P. "Space Hardware Displayed", ***Spaceflight***, January 1988, p.15.
2 Devereux T. "Energia Payload Engine", ***Spaceflight***, February 1988, p 70.
3 Salmon M "Energia Nozzle Design", ***Spaceflight***, February 1988, p.72.
4. Lawton A.T "Energia – Soviet Super Rocket", ***Spaceflight*** August 1987, p.285.
5 "Advanced Chemical Rocket Propulsion", Academic Press, 1987
6. "Aerospike Engine Technology Demonstration for Space Propulsion", AIAA Paper No. 74-1080 (1974).

SHUTTLE

The Return to Flight

The United States is back in space. Spaceflight begins its extensive coverage with the first part of our STS-26 Mission Report. We begin with the build up to the successful flight and continue our report with an article by Philip Chien, who was at the Kennedy Space Center for the launch.

Discovery was selected as the Space Shuttle for the STS-26 mission in 1986. At the time of the 51-L accident Discovery was in temporary storage in the Kennedy Space Center (KSC) Vehicle Assembly Building (VAB) awaiting transfer to the Orbiter Processing Facility (OPF) for preparation for the first Shuttle flight from Vandenberg Air Force Base, California, scheduled for later that year. Discovery last flew in August 1985 on Shuttle mission 51-I, the orbiter's sixth flight since it joined the fleet in November 1983.

In January 1986, the Shuttle Atlantis was in the OPF, prepared for the Galileo mission and ready to be mated to the boosters and tank in the VAB. The orbiter Columbia had just completed the 61-C mission a few weeks prior to the accident and was also in the OPF undergoing post-flight deconfiguration.

Various Shuttle manifest options were being considered, and it was determined that Atlantis would be rolled out to Launch Pad 39-B for fit checks of new weather protection modifications and for an emergency egress exercise and a countdown demonstration test. During that year it also was decided that Columbia would be flown to Vandenberg for fit checks. Discovery was then selected for the STS-26 mission.

Discovery was moved from the VAB High Bay 2, where it was in temporary storage, into the OPF the last week of June 1986. Power up modifications were active on the orbiter's systems until mid-September 1986 when Discovery was transferred to the VAB while facility modifications were performed in Bay 1 of the OPF.

Discovery was moved back into the OPF Bay 1 on October 30, 1986, a milestone that initiated an extensive modification and processing flow to ready the vehicle for flight. The hiatus in launching offered an opportunity to "tune-up" and fully check out all of the orbiter's systems and treat the orbiter as if it was a new vehicle. Most of the orbiter's major systems and components were removed and sent to the respective vendors for modifications or to be rebuilt.

After an extensive powered-down period of six months, which began in February 1987, Discovery's systems were awakened when power surged through its electrical systems on August 3, 1987.

Discovery remained in the OPF while workers implemented over 200 modifications and outfitted the payload bay for the Tracking and Data Relay Satellite.

Flight processing began in mid-September during which the major components of the vehicle were reinstalled and checked out, including the main engines, the right and left hand orbital manoeuvring system pods and the forward reaction control system.

In January 1988, Discovery's three main engines arrived at KSC and were installed. Engine 2019 arrived January 6, 1988, and was installed in the number one position January 10. Engine 2022 arrived January 15 and was installed in the number 2 position January 24. Engine 2028 arrived January 21 and was installed in the number 3 position also on January 24.

The redesigned solid rocket motor segments began arriving at KSC March 1, and the first segment, the left aft booster, was stacked on Mobile Launcher 2 in VAB High Bay 3 on March 29. Technicians started with the left aft booster and continued stacking the four left hand segments before beginning the right hand segments on May 5. The forward assemblies/nose cones were attached May 27 and 28. The SRB field joints were closed out prior to mating the external tank to the boosters on June 10. An interface test between the boosters and tank was conducted a few days later to verify the connections.

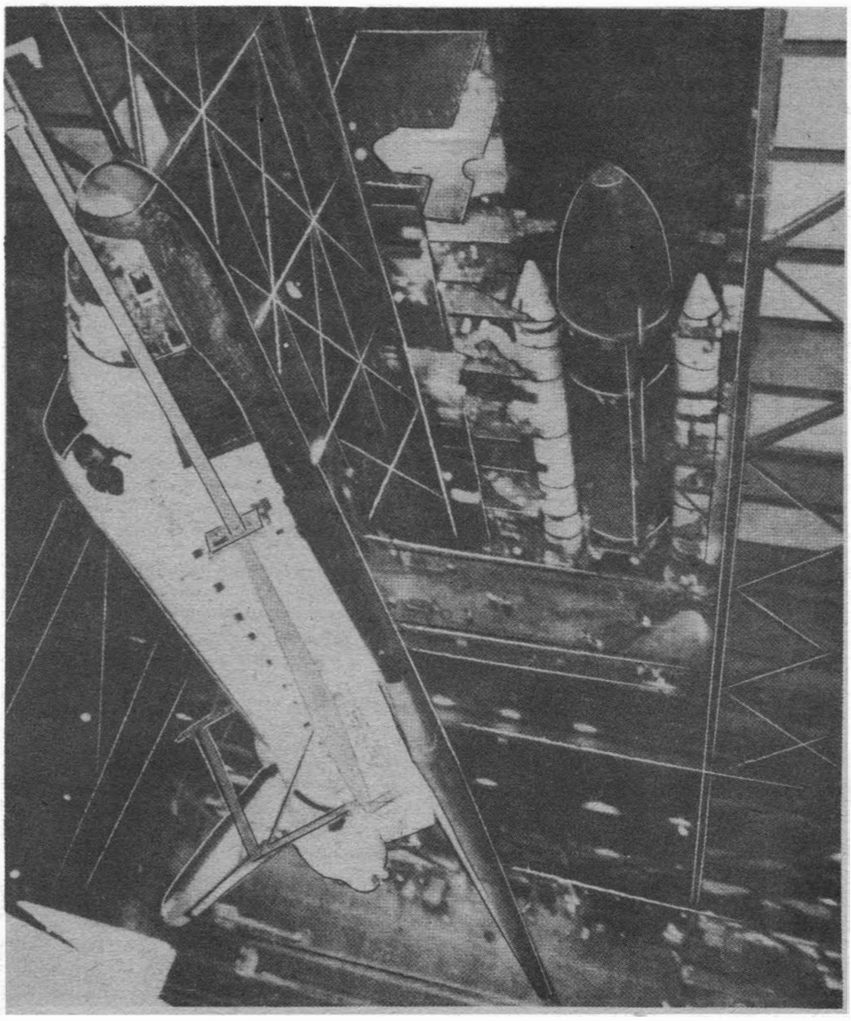
The OASIS payload was installed in Discovery's payload bay on April 19.

The TDRS arrived at the Vertical Processing Facility on May 16, and its Inertial Upper Stage (IUS) arrived May 24. The TDRS/IUS mechanical mating was accomplished on May 31.

Discovery was moved from the OPF to the VAB June 21, where it was mated to the external tank and solid rocket boosters. A Shuttle Interface Test was conducted shortly after the mate to check out the mechanical and electrical connections between the various elements of the Shuttle vehicle and the function of the onboard flight systems.

The assembled Space Shuttle vehicle aboard its mobile launcher platform was rolled out of the VAB on July 4, 4.2 miles to Launch Pad 39-B for a few major tests and

Orbiter Discovery in the vertical hoist position in the Vehicle Assembly Building in preparation for mating with the STS-26 stack. *NASA*



final launch preparations.

A few days after Discovery's orbital manoeuvring system pods were loaded with hypergolic propellants, a tiny leak was detected in the left pod (June 14). Through the use of a small, snake-like, fiber optics television camera, called a Cobra borescope, workers pinpointed the leak to a dynatube fitting in the vent line for the reaction control system nitrogen tetroxide storage tank, located in the top of the OMS pod.

The tiny leak was stabilised and controlled by "pulse-purging" the tank with helium – an inert gas. Pulse-purge is an automatic method of maintaining a certain amount of helium in the tank. In addition, console operators in the Launch Control Center firing room monitored the tank for any change that may have required immediate attention. It was determined that the leak would not affect the scheduled Wet Countdown Demonstration Test (WCDDT) and the Flight Readiness Firing (FRF) and repair was delayed until after these important tests.

The WCDDT, in which the external tank was loaded with liquid oxygen and liquid hydrogen, was conducted August 1. A few problems with ground support equipment resulted in unplanned holds during the course of the countdown.

A leak in the hydrogen umbilical connection at the Shuttle tail service mast developed while liquid hydrogen was being loaded into the external tank. Engineers traced the leak to a pressure monitoring connector. During the WCDDT, the leak developed again. The test was completed with the liquid hydrogen tank partially full and the special tanking tests were deleted. Seals in the 8-inch fill line in the tail service mast were replaced and leak checked prior to the FRF.

In addition, the loading pumps in the liquid oxygen storage farm were not functioning properly. The pumps and their associated motors were repaired.

After an aborted first attempt, the 22-second flight readiness firing of Discovery's main engines was conducted August 10. The first FRF attempt was halted inside the T-10 second mark due to a sluggish fuel bleed valve on the number 2 main engine. This valve was replaced prior to the FRF. This firing verified that the entire Shuttle system – including launch equipment, flight hardware and the launch team – were ready for flight. With over 700 pieces of instrumentation installed on the vehicle elements and launch pad, the test provided engineers with valuable data, including characteristics of the redesigned solid rocket boosters.

After the test, a team of Rockwell technicians began repairs to the OMS pod leak. Four holes were cut into two bulkheads with an air powered router on August 17. A metal "clamshell" device was bolted around the leaking dynatube fitting. The clamshell was filled with Furmanite – a dark thick material which consists of graphite, silicon and heavy grease and glass fiber. After an initial leak check was successfully performed, covers were bolted over the holes August 19, and the tank was pressurised to monitor any decay. No leakage or decay in pressure was noted and the fix was deemed a success.

TDRS-C and its IUS upper stage were transferred from the VPF to Launch Pad 39-B on August 15. The payload was installed into Discovery's payload bay August 29.

A countdown Demonstration test took place on September 8, during which the crew boarded Discovery and went through the countdown procedure until the T-4 seconds point. After leaving the orbiter the crew practiced their emergency evacuation plans.

A Launch Readiness Review was conducted on September 14 and 15 to set a date for launch. NASA's announcement was delayed until September 16, because of concern that the approaching Hurricane Gilbert would threaten Mission Control and training facilities at the Johnson Space Center. Later forecasts indicated the storm would not endanger the JSC and the launch was set for September 29 at 09:59 EDT.

Philip Chien continues this special feature with a report on the final days before launch and the successful blast-off.

September 28, 1988 4:20 AM – It's an old feeling which has not occurred in a long time. The countdown is running, and the shuttle's on the pad. It's been two years and eight months since we have had a shuttle countdown running and that's much too long. For this reporter it's an unusual feeling, a sense of unrealness. It's hard to believe that a countdown clock is underway while I am writing these words – it's been too long and after all the delays it's hard to believe that it's started so smoothly.

Green ribbons and balloons have appeared everywhere, local residents indicating their support for the shuttle, and wishing the Discovery crew a safe flight.

NASA has received over 4,000 requests from members of the press for access to the space center – in comparison there were only 500 requests for the 51-L Challenger flight. 61 mobile television trucks from as far away as New York city and Minneapolis Minnesota are in place at the press site.

Range Safety

Besides the higher than normal number of newspeople there's also another significant difference. Only 1,800 photographers, reporters, and technicians will be permitted at the Complex 39 press site 3.5 miles from the launch pad. The other 2,200 journalists expected to attend are forced to cover the flight from an alternate site twice as far away from the pad. The apparent logic is that it's okay to kill 1,800 journalists, and a couple of thousand NASA and contractor personnel, but another 2,200 would not be acceptable. One VIP site is open, about five miles from the pad. It's apparently going to be filled with 'expendable' VIP'. Three other VIP sites, including a brand new one built specifically for Pad B will remain unused.

So what caused this decision to move people back from the pad? While the official announcements say "safety" – the actual reason is a power play between the Air Force range safety people and the NASA flight controllers at the Johnson Space Center (JSC). According to the Air Force the safety studies they performed after the Challenger accident and an accident involving a secret Titan 34D launch from Vandenberg Air Force Base indicated the original safety restrictions were too loose and had to be tightened. Originally no members of the press, and only the most necessary launch personnel would be permitted within twelve miles of the launch pad. With the limit my neighbours and I would have to be evacuated from our houses to keep range safety happy! After several months of negotiations between NASA and the Air Force, the compromise was reached where 1,800 journalists, and all daily NASA personnel were permitted to remain in normal launch viewing sites, but VIPs and the general public would be restricted to other sites at least 5 miles away from the launch pad.

The official justification is that if the shuttle should go out of control the astronauts will have approximately one second extra to attempt to get it back under control before the range safety officer would have to destroy the shuttle.

Are the alternate viewing sites any safer than the closer sites? Undoubtedly simply because the further away you are the less likely you are to be hit by any debris or shrapnel if there's a worst case explosion early in the flight. On the other hand, is seven miles really that much safer than three miles?

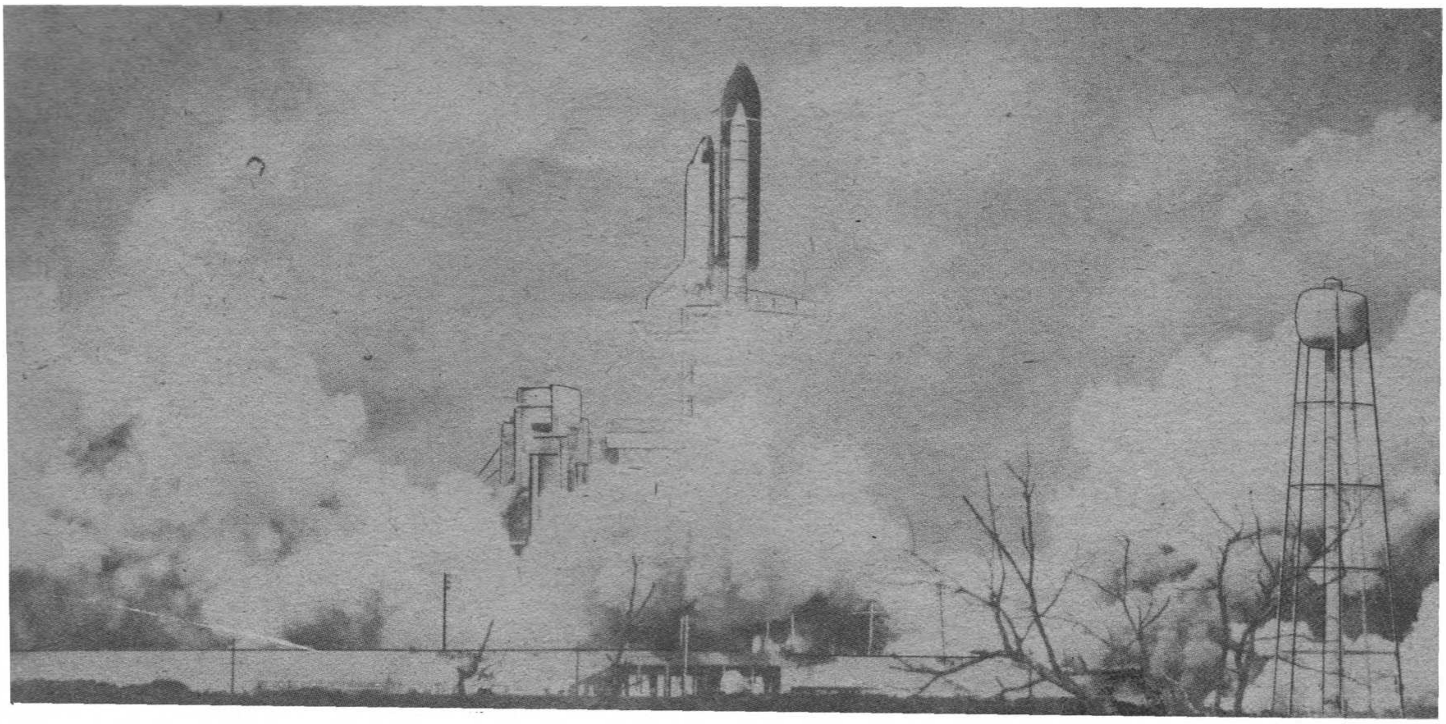
So what's the real reason for the new rules? As the range safety rules currently stand, the shuttle is controlled in flight by the NASA flight dynamics officer at the JSC. While Range Safety monitors the flight of the shuttle, it "belongs" to JSC. Should the shuttle go out of its flight path the range safety officer has to get permission from the flight dynamics officer before destroying the vehicle. Range Safety's justification for the new rules is that if it has full control over the vehicle it can destroy it earlier, before it goes out of the normal flight safety zone. Unfortunately the JSC flight dynamics people refused to give up control of the shuttle, and consequently journalists and VIPs were moved away from their normal viewing sites.

How do journalists feel? Those who realize the situation and the causes are not happy about it. As professional journalists, most of us believe in the concept "acceptable risk". If I cover a riot, a battle during a war, an air show, or any other "dangerous" assignment then there's an acceptable risk. Journalists, as well as the public, should be informed as to what the risk is, and make the decisions for themselves as to whether or not the risk is worthwhile. Walking across the street or driving home from the space center are both more dangerous activities than watching a shuttle flight from up close. For myself, even with the new Air Force studies based on the Challenger and Titan 34D accidents, the risk of being at the Complex 39 press site is totally acceptable.

Safety engineers have questioned the validity of the conclusions in the study, which the Air Force has never released to the public. Consequently the Air Force ordered the study, verified it, rubber stamped its accuracy, and forced its conclusions.

Is the alternate press site any safer than the normal press site? I can confirm that the alternate press site is certainly much more dangerous than the Complex 39 site. At the alternate site I was bitten by bugs, got sunburned, and got sand burrs in my shoes!

The only potential technical problem which could delay the flight is not associated with the upper stage, IUS, to be used on this flight. Boeing technicians were examining another IUS, one scheduled for use on a future Discovery flight with another TDRS payload when they found a scratched O-ring seal. That O-ring is used to seal the igniter for the second stage of the



Discovery launches America back into space

IUS. Careful examination showed that the scratch in the O-ring was caused by an improperly smoothed screw mechanism used to hold the igniter and O-ring in place. Since the same inspection team had checked out the IUS in Discovery's payload bay and qualified it for flight, managers were confident that the IUS aboard Discovery did not have any problems. In addition a test was done with a flawed O-ring which determined that even under the full 1615 PSI flight pressure, the seal would not leak.

Launch Day

There's a sight I have not seen in a long time! Crowds! U.S. 1 in Titusville is filled with hundreds of cars packing every available space on the side of the road. Many people are sleeping on blankets on the grass outside of their cars. The weather's a perfect Florida fall night – slightly cool and extremely comfortable. Air Force weather officers have predicted that there's at least an 80 per cent chance that the weather will be good enough for launch.

As it turns out the weather – always a problem with shuttle flights is too good for flight! Normally high altitude winds in the fall are fairly high, and the flight software is designed to compensate for the winds. But today the winds are rather low and more like springtime winds. It is possible to change the flight software, but not in enough time within today's launch window. Consequently the launch window, and expected launch time have been pushed back an hour with launch scheduled no earlier then 10:59 am EDT. It's hoped that the high level winds will pick up, and match the predictions and flight software more closely, permitting a launch today. Ironically all of the orbiter's systems are operating perfectly, and showing no problems. Currently at T- 1 hr, there's only one cause for concern – fuses on the suit fans which cool the astronauts while they are in their survival partial-pressure suits. Commander Rick Hauck is sitting in his couch, and his fan is operating perfectly. But Pilot Dick Covey, and Mission Specialist Pinky Nelson's fans are not operational, and the launch crew is attempting to track down the person with the spare fuses! Extra fuses were found, and all five suit fans are operational and ready for flight, Just in case, the crew is storing several extra 5 amp fuses in the flight cabin.

Ironically it was just four years ago that a shuttle launch was delayed one day due to high level winds. Commander Rick Hauck should remember that event quite well – he was the commander on that flight also, and it was also Discovery, her second flight STS-51-A, the mission which launched two satellites and retrieved two others.

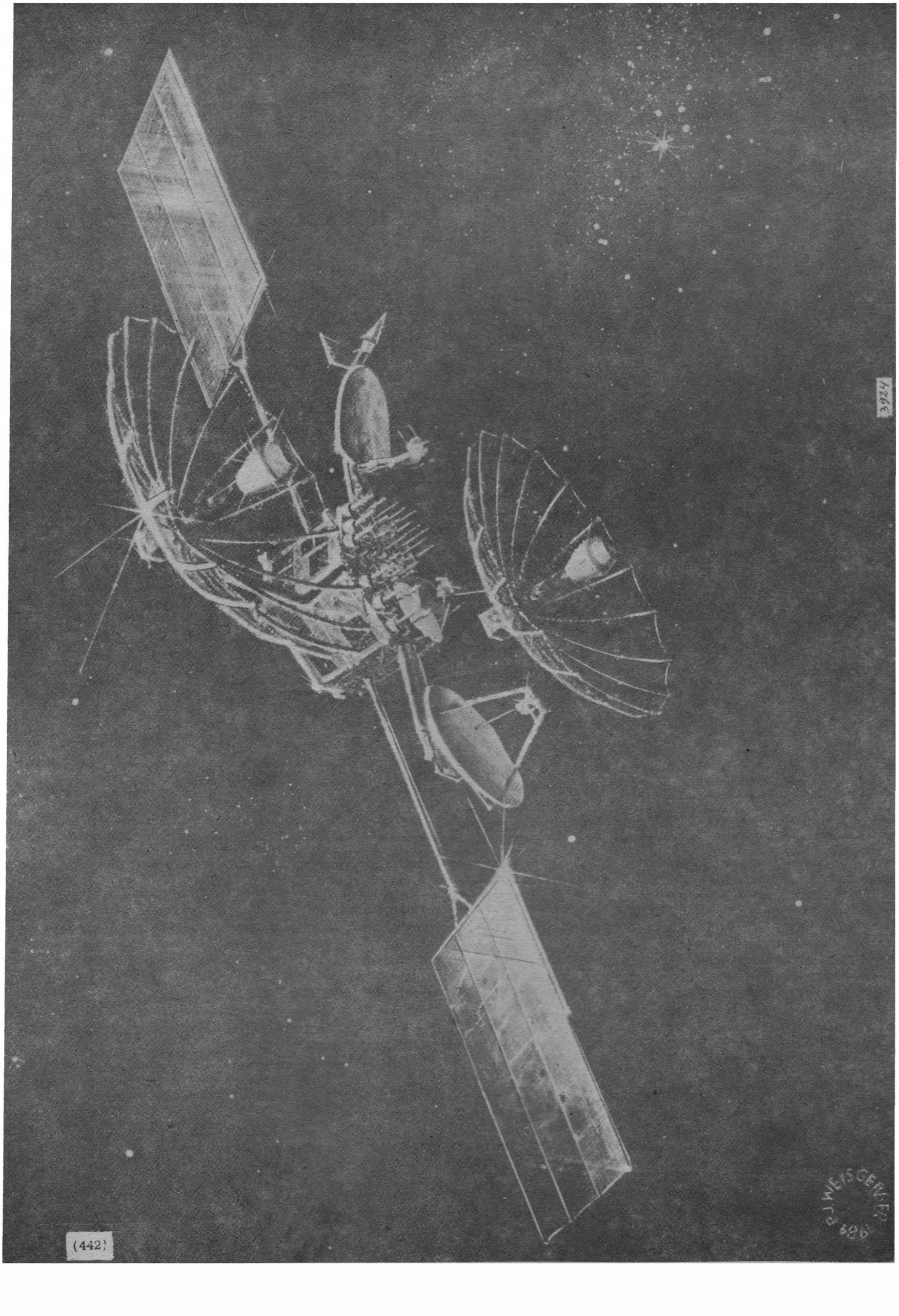
Weather here on the ground looks perfect. It's clear fall day, and the early morning fog has burned off. There's less than five per cent cloud cover, and weather at the emergency Return To Launch Site landing strip is adequate. TransAtlantic and Abort Once Around sites, other emergency abort locations, are also reporting adequate weather conditions. The only limiting factor to launch at this time is the high altitude winds.

Extra extensions are added to holds in the countdown in the hope that the weather will improve. The launch crew and flight dynamics engineers examine Discovery's flight characteristics and the weather situation and have decided that even with the current weather there's still a 1.4 safety margin and give the go ahead for launch. As shuttle operations director Tom Utsman remarked afterwards "It [the weather] required a waiver, but it was not a judgement call, it was decided with careful engineering analysis."

During the T-9 minute hold Deputy Shuttle director Bob Crippen, an astronaut who has flown on four shuttle flights, polls the launch team for a go/no go situation. With one exception he gets a go signal from every person in the team. The exception is the technician examining the cabin oxygen pressure. A sensor may give an incorrect reading causing the countdown to automatically stop at T-31 seconds scrubbing the flight for the day. It is decided to use a work-around to solve the problem. The crew will close their helmet visors later in the countdown which will hopefully stop the incorrect readings.

The countdown picks up at 11:28 am with an expected T-0 of 11:37 am. Very quickly several members of the press realize that that's only one minute difference from the 11:38 am liftoff time of Challenger on her last flight. The countdown proceeds without any incidents towards an on time launch. Suddenly an announcement comes out that the launch computer has announced that there will be a hold at the T-31 seconds. A large groan comes from the viewing sites – so close but so far. But quickly an explanation comes, that hold indicator has come from the cabin oxygen indicator, a recognised problem which does not cause any concern. The "flag" is removed from the computer, and the countdown proceeds without any problems. It approaches zero and at the T-6 second mark the main engines come to life again. The T-0 occurs at 11:37:00.687 am EDT – less than seven tenths of a second late. Liftoff is perfect as the shuttle goes through its roll manoeuvre. Capcom J.O. Creigthton in Houston starts calling out critical systems calls to the astronauts, and as each milestone is passed there is applause from the crowds. When Discovery passes through the period of Max Q – maximum flight pressure and the "throttle up". – the point where the Challenger accident occurred – a massive cheer comes from not just the crowd on the ground, but also from the cockpit of Discovery, and the flight controllers on the ground. The redesigned solid rocket motors finish their jobs perfectly and are dropped off right on schedule. Some reporters without any engineering knowledge noticed "flames" coming from the bottom of the left SRB, but engineers confirmed that the "flames" were actually an illusion. When the SRBs were recovered from the sea it was confirmed that there were no burn marks on the SRBs. Eight minutes after launch the shuttle's main engines shut down on schedule and the External Tank is dropped for an eventual burn up in the ocean South of Hawaii. The crew is in space, and 34 minutes later the small OMS – Orbiter Manoeuvring System engines are fired placing Discovery into a perfect circular orbit – the United States has returned to Space once again!

This Mission Report will be continued in the December edition of *Spaceflight*. Turn over for details of Discovery's payload and a preview of the next mission.



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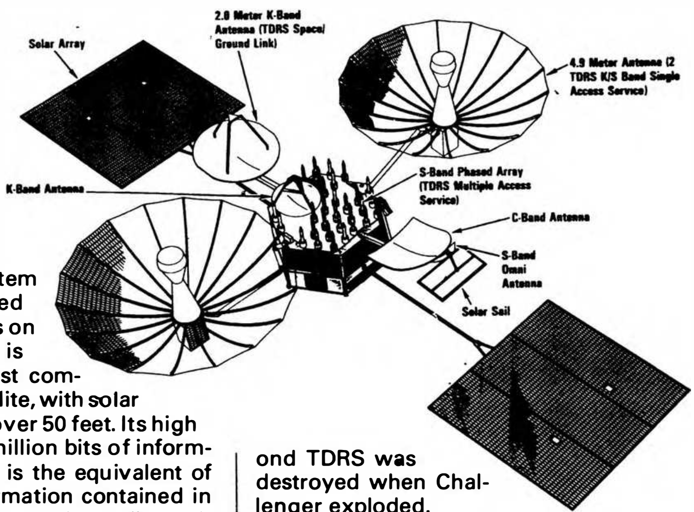
TDRS-C

Payload for Discovery



The second Tracking and Data Relay Satellite (TDRS) was successfully deployed by Discovery during STS-26 on September 29. The TDRSs relay communications from satellites in low-Earth orbit to a single ground station on Earth, the system is vital for shuttle operations.

Prior to the launch of the first TDRS in 1983 Mission Control relied solely on the ground network, a series of stations scattered around the globe, that together allowed less than 20 minutes of contact with the shuttle during each 90 minute orbit. The first TDRS increased the communications time to 50 minutes each orbit, once TDRS-C becomes operational the shuttle will remain in contact for about 77 minutes each orbit. TDRS-C is to be renamed TDRS-3 once it is certified operational.

Since the start of the manned space programme work at Mission Control has revolved around a staccato rhythm of Acquisition of Signal (AOS) and Loss of Signal (LOS). Chuck Shaw, shuttle flight director explains how this will change life in Mission Control.

"Flexability is the big thing – we don't have to wait until all the stars line up to talk to the crew." At times certain events have to be geared to coincide with the AOS from ground stations, he explained. "For instance, we had to schedule payload tests while we were over one. To me that's the biggest single impact – to not have to do things at specific times just because of network coverage." Shaw said.

The TDRS system may shorten the communications blackout experienced during the orbiter's re-entry into the atmosphere. Gary Coen, an ascent and re-entry flight director, added. "We'll be able to talk with the crew much earlier before the second deorbit burn with the second TDRS up and we should have some extra signal strength during re-entry. But it remains to be seen how much," Coen said.

The TDRS system will increase shuttle safety, previously if a malfunction occurred during LOS it could be 30 - 40 minutes before flight controllers received the information and were able to suggest a remedy to the crew.

An artist's impression of the Tracking and Data Relay Satellite in geostationary orbit. ***TRW***

The TDRS system is privately owned by CONTEL and is on lease to NASA. It is the world's largest communications satellite, with solar arrays spanning over 50 feet. Its high data rate of 300 million bits of information per second is the equivalent of relaying the information contained in 100 volumes of an enclyopedia each second.

Each TDRS weighs nearly 2,200kg. Its giant solar arrays will generate more than 1,700 watts of electrical power for 10 years.

The satellite has two antennas for S-band and Ku-band transmissions measuring 4.9m in diameter, which open up like giant umbrellas at the tips of appendages. The surface of each antenna is a gold platted wire mesh.

The TDRS Network

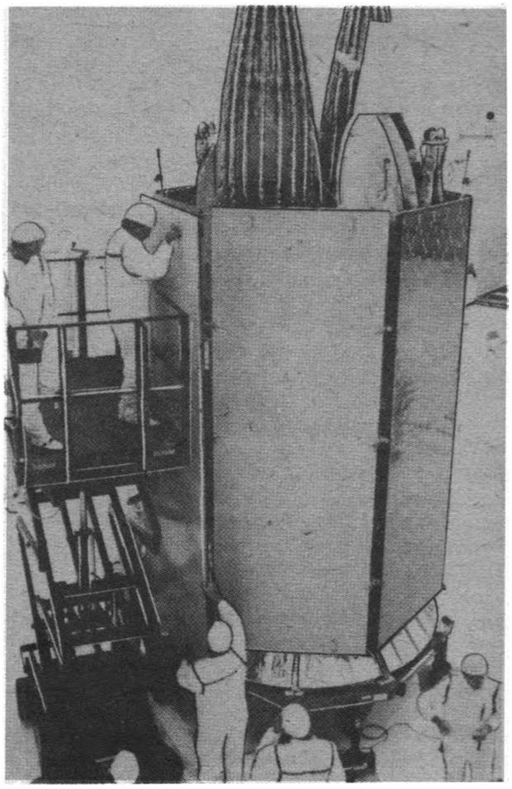
Once fully operational TDRS will provide tracking and communications for up to 40 separate users (up to 26 can operate simultaneously), offering coverage from 85 to 100 per cent of the satellites' orbits, depending on their altitude above the Earth. This expanded coverage may eventually permit NASA to close a large number of expensive overseas tracking stations.

All satellite telemetry relayed by TDRS is funneled through an automated ground station at White Sands, New Mexico. NASA then routes the data to various field centres, such as the Johnson Space Center for shuttle flights; or to the Goddard Space Flight Center for unmanned missions.

Once released from the shuttle's cargo bay TDRS is boosted to its geostationary orbit by a US Air Force developed Inertial Upper Stage (IUS). Problems with this upper stage caused the TDRS deployment to be delayed. The first TDRS satellite was placed into the wrong orbit when the second stage of its IUS failed. The satellite was almost lost, but NASA and TRW engineers managed to manoeuver the satellite into its geostationary orbit by using TDRS's small one-pound thrusters. Deployment of the TDRS system was postponed until the IUS problem was rectified. The upper stage was successfully tested during two classified DoD shuttle missions in 1985. The second TDRS was destroyed when Challenger exploded.

The fully operational TDRS system consists of three satellites in orbit with one designated an on-orbit spare. When the TDRS-D is deployed by Discovery in February 1989, it will replace the aging and trouble hit TDRS-1, which will become the spare satellite. Three replacement satellites will be launched as required, two are currently being completed by the manufacturers, TRW, and the third is to be built as a replacement for TDRS-B which was lost in the Challenger accident. Studies are also underway for a second generation TDRS system.

Final inspection of TDRS-C in the clean room of the Vertical Processing Facility at KSC.

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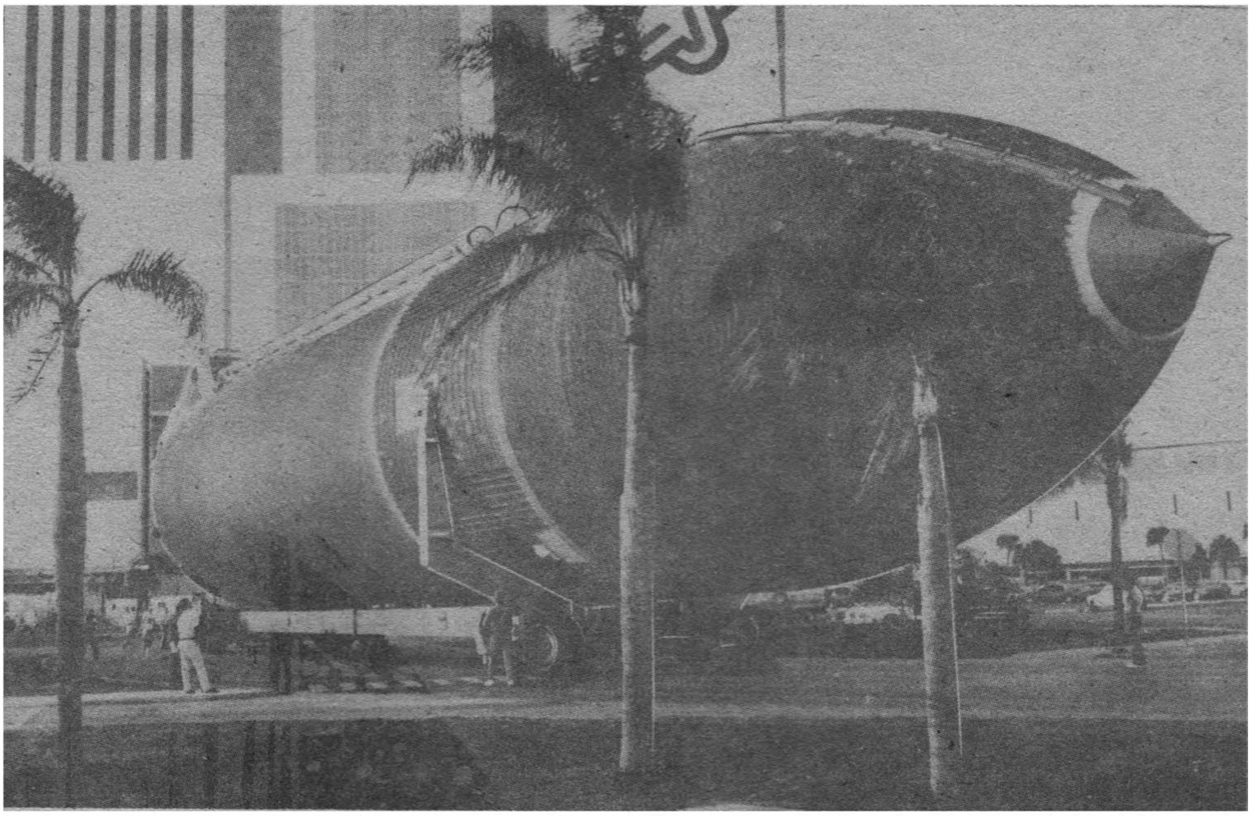
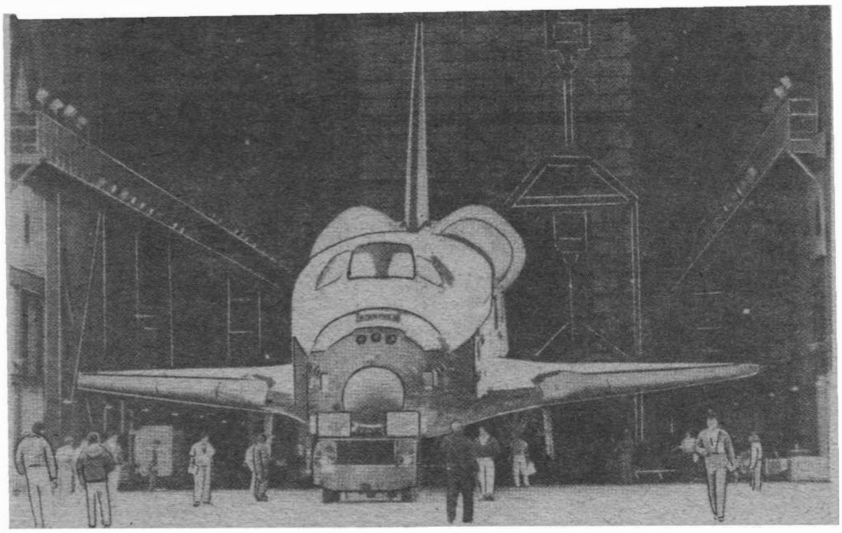


Shuttle Military Mission

Later this month the Space Shuttle Atlantis will be launched from the Kennedy Space Center on STS-27, a classified Department of Defense (DoD) mission. *Spaceflight*, continues it unrivalled Shuttle coverage with a report on this secret mission.

At the time of going to press Atlantis was scheduled for a November 17 launch, however a delay of at least a week seems likely. The actual lift-off time on launch day will remain secret until the T-9 minutes point. This will be the third dedicated DoD mission, there were two military shuttle flights in 1985 (STS 51-C and STS 51-J).

The crew for STS-27 consists of three members of the STS 62-A mission which was to have been the first shuttle launch from Vandenberg Air Force Base. The mission was cancelled following the Challenger accident.



Atlantis under tow during preparations for STS-27. *NASA*

Commander Robert (Hoot) Gibson

Born on October 30, 1946 Gibson holds the rank of Commander in the US Navy, he is a Vietnam veteran and has flown 56 combat missions. He joined NASA in August 1978 as an astronaut pilot. Gibson has made two space flights, he piloted Challenger on STS 41-B in February 1984 and was the commander of STS 61-C in January 1986, the last flight before the Challenger accident. Gibson participated in the simulated countdown and emergency escape rehearsal when Atlantis was moved to the pad in October 1986. Gibson is married to shuttle astronaut Rhea Seddon.

Pilot Guy Gardner

Gardner was born on January 6 1948 and is a Colonel in the US Air Force. He joined NASA in May 1980 as a Group 9 astronaut pilot and has not yet flown in space. Gardner was to pilot Discovery on STS 62-A. (He should not be confused with Mission Specialist Dale Gardner).

Mission Specialist Richard Mullane

Mullane a Lt. Colonel in the US Air Force was born on September 10, 1945. He joined NASA in August 1978 and made his first space flight on STS 41-D in August 1984. He was to have been a mission specialist for STS 62-A.

Mission Specialist Jerry Ross

Ross was born on January 20, 1948. He is a Lt. Colonel in the US Air Force. Ross joined the NASA Group 9 astronauts in May 1980 and made his first space flight in November 1985 on STS 61-B during which he made a space walk to assemble the ACCESS and EASE structures. Ross was to have been a mission specialist on STS 62-A.

Mission Specialist William Shephard

Shephard a Lt. Commander in the US Navy was born on July 26, 1949. He joined NASA in the Group 10 astronaut selection in May 1984. STS-27 will be his first space flight.

Preparations for STS-27 began in March 1987 when Atlantis was rolled from the Vehicle Assembly Building (VAB) to the Orbiter Processing Facility (OPF) Bay 2. At this point the Orbiter was minus its three main engines. After extensive testing the engines were returned to Atlantis. Their installation was completed in September. Modifications made to Discovery have also been carried out on Atlantis and the whole Orbiter has undergone a rigorous examination. Last minute preparations included; fitting the Ku-Band antenna in its flight position; testing the OMS; leak checks on the main engines and installation of heat resistant tiles on Atlantis' external surfaces.

In the VAB stacking of the Solid Rocket Boosters (SRB) on Mobile Launch Platform 2 was completed in early October. The External Tank (ET), which arrived at the Kennedy Space Center in March 1988, underwent final tests in High Bay 4 of the VAB. It was then mated to the two SRBs.

Atlantis was due to be transferred to the VAB in mid-October for the five day operation to mate it with the ET/SRB stack, a roll-out to pad 39B was expected in late October.

After completing its classified mission Atlantis will land at Edwards Air Force Base in California.

(Above) The astronauts for STS-27 pose for their traditional crew photograph. (Seated left to right) Guy S. Gardner, Robert L. Gibson and Jerry L. Ross and (standing left to right) William M. Shepherd and Richard M.(Mike) Mullane. The mission patch depicts the Space Shuttle lifting off against the multi-coloured backdrop of a rainbow, symbolising the triumphal return to flight for the US manned space programme. The design also commemorates the memory of the crew of Challenger mission 51-L, represented by the seven stars. The crew helped to design the patch.

(Below) The STS-27 External Tank arrives at the Kennedy Space Center, it was transported to the Cape on an ocean going barge. *NASA*

Shuttle Fleet Status

Discovery OV-103

Following its successful four day flight Discovery has been returned to the Kennedy Space Center (KSC) atop the Boeing 747 Shuttle Carrier Aircraft (SCA).

Soon after landing at Edwards Air Force Base on October 3 work began to return the Orbiter to its launch site. Fuel remaining onboard Discovery was drained, and unused pyrotechnic devices were removed. During an inspection of the Orbiter's protective tiles "a diamond shaped abrasion" was discovered on the right hand wing. The "abrasion" was covered for the return flight to KSC to prevent any further erosion of the tiles. There are two possible theories on the the cause of this damage. Discovery may have struck a bird during launch or landing, alternatively the Shuttle may have been hit by a piece of orbital debris during the flight.

Discovery's main engines were enclosed within the tail cone, a protective structure which reduces aerodynamic stress on the 747 and prevents damage to the shuttle engines.

The SCA and Discovery took off from Edwards AFB at 10:54 am (EDT), the 747 stopped for refuelling at Kelly Air Force Base in San Antonio, Texas. The SCA touched down at KSC at 7:04 pm (EDT) completing its flight across the US. Discovery is now in the Orbiter Processing Facility (OPF).

Columbia OV-101

Work continues in bay 1 of the OPF on Columbia, this Orbiter was rolled there from the Orbiter Maintenance and Refurbishment Facility to the OPF on July 8.

A variety of inspections and modifications of the Orbiter are underway. Columbia is scheduled to make the STS-28 DoD mission in July 1989.

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Mir Space Walk

Spaceflight

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SPACE AT JPL

Vol. 30 No. 12

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Front Cover: A dramatic artist's impression by Kristian Brugts portrays a successful lift-off of the Soviet shuttle 'Buran' by the Energia rocket. See p.450 for a special report on the Soviet shuttle system and p.454 for an account of recent events at the Mir space station.

SOVIET SHUTTLE

The Soviet shuttle is a revolutionary step forward for the USSR's space programme. Although the first launch attempt was aborted the fault was with ground equipment not the spacecraft itself. A vehicle of such complexity must expect to suffer these minor hitches. In conjunction with the Energia heavy lift booster the Soviet Union has a powerful space transportation system. In this special *Spaceflight* report we take a detailed look at the Soviet shuttle system.

The VKK System

VKK stands for Vozdushno-Kosmicheskiy Korabl or in English Air-Spacecraft. This name is probably the counterpart for the US STS (Space Transportation System) designation. So it would be reasonable to refer to the first test flight as VKK-1.

The VKK system began its development in 1978 and has cost the equivilant of US $10 billion.

The Soviet shuttle bares a startling resemblence to the US version. The Soviets say "this similarity has been prompted by laws of aerodynamics". To a certain extent this is true, but it is obvious the USSR has learnt alot from the openly published literature on the US shuttle.

It is not only technical experience they have gained from the US shuttle programme. The Soviets will not make the mistake of abandoning their expendable rocket fleet. The VKK will be used for missions which only it can perform, e.g. the retrieval of satellites.

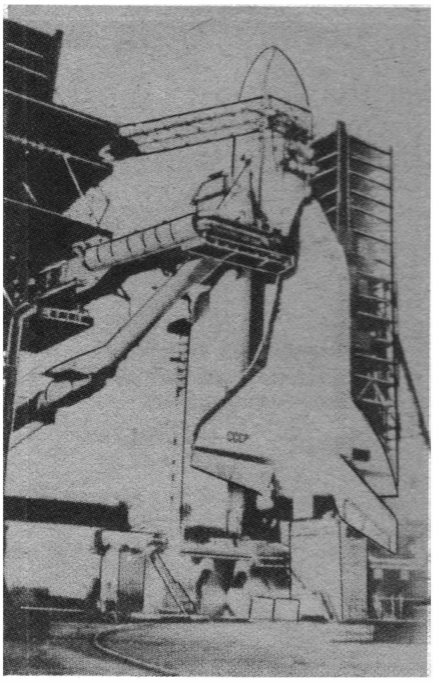
Ferrying cosmonauts to the Mir space station will remain a task for the Soyuz TM capsules. However when the larger Mir-2 complex is launched by Energia in 1994-1995 the shuttle may be used to carry a large crew, of about ten cosmonauts, to the station.

In the next few years we can expect few Soviet shuttle flights, a Glavkosmos official told ***Spaceflight*** the Energia booster would initially make only two flights a year.

The VKK is slightly larger than its US counterpart, detailed dimensions of the vehicle have not been made available. However, one Soviet report states the vehicle has a fuselage diameter of 5.6 metres, larger than the US shuttle's 5.17 metre diameter.

The main difference between the two shuttles is the absence of main engines from the VKK. The Energia booster carries the propulsion system and can operate independently from the shuttle by using a cargo pod. The Americans are only just beginning to investigate the possibility of using a cargo pod instead of an orbiter with the Shuttle-C concept.

The orbital manoeuvering engines of the Soviet shuttle are located on the rear bulkhead where you would expect to find the US main engines. Smaller manoeuvering thrusters are located in pods that emerge from the rear of the orbiter and are also located in the nose area.



Novosti

The surface of the VKK orbiter is covered in lightweight heat absorbing ceramic tiles. Exactly the same system as the US shuttle uses for reentry. The US shuttle has about 30,000 of these tiles compared with 38,000 on the VKK orbiter.

The VKK can have a crew of two to four cosmonauts and six passengers, giving a full crew complement of ten, the standard crew will be of seven. The 'passengers' refered to in Soviet reports will probably be Cosmonaut Researchers, the equilivant to the US Mission, or Payload Specialists.

The shuttle cosmonaut corp suffered a double blow this year. On August 6 cosmonaut Anatoliy Levchenko died of a brain tumour (***Spaceflight***, October 1988, p.381). It has just been revealed that Levchenko's back up, Alexander Shchukin, died almost two weeks later on August 18. Shchukin was killed when his Sukhoi Su-26M aircraft crashed.

The death of these two cosmonauts means the first manned shuttle will probably be flown by Igor Volk and Ural Sultanov, the two other cosmonauts to be officially named as shuttle pilots.

The Soviet shuttle does not appear to have a crew escape system for inflight aborts, no ejection panels are visible.

If a malfunction occurs early in the flight the orbiter can separate from Energia and make a Return to Launch Site abort, touching down on a runway at the Baikonur Cosmodrome. In addition to the launch site the Soviet shuttle may be able to land on an airstrip down range from the launch site. The US shuttle does not have this option because its is launched across the Atlantic Ocean.

The VKK can also make one low orbit of the Earth and then make a landing, the equilivant of a US Abort Once Around.

The Soviet shuttle is thought to use fuel coils, if so it will be a first for the Soviet space programme. Fuel cells produce electricity by combining hydrogen and oxygen with water as a by product. The United States has used

fuel cells on its spacecraft since the Gemini programme, the Soviet Union uses solar panels to power its spacecraft. It is possible the VKK is solar powered, it could deploy a large solar array from the payload bay, however this could affect on-orbit operations.

The entire Energia/shuttle combination weighs 2,400 tonnes, fuel accounts for over 2,000 tonnes. Energia's mass has been reduced by taking into account the effect low temperatures have of increasing metal strength.

The Soviet Shuttle Fleet

The Soviet Union has at least three space-ready orbiters, two of these have been identified. The first is Buran or 'Snowstorm'. The second was shown to journalists in one of the Assembly and Test Buildings, it is named 'Birdie'.

There was at least one orbiter that performed duties similar to those of the US shuttle Enterprise. One orbiter was carried piggyback atop a Bison aircraft and released for approach and landing tests. An orbiter with strap-on jet engines is also thought to exist. Cosmonauts take-off using the jet engines then shut them down and practice gliding to a runway.

Another orbiter was rolled out to the pad on an Engeria booster to test the pad equipment, this operation has taken place several times.

The first photograph of the Soviet shuttle had its name masked out and its makings seem to differ from those of Buran. The implication is this was not Buran and was another member of the fleet. However, it may simply have been an effort to keep the name Buran secret.

The First Launch Attempt

According to Soviet television the massive Energia/Buran combination was moved from its hanger to the new shuttle launch pad on October 23.

VKK-1 is to be unmanned, and will land automatically. It is the automatic landing system that has proved most difficult to perfect. It has been reported that cosmonaut Igor Volk has disagreed with the policy of flying the first shuttle flight unmanned. If the automatic landing system was to fail there would be no way of saving Buran. If the shuttle was manned a cosmonaut would be able to take over said Volk.

Buran was to make two orbits of the globe during its first test flight which would last about three hours. It would then land at a specially constructed runway at the Baikonur Cosmodrome located just 12km from the launch pad.

The Soviets had promised to release the launch time in advance, the date and time was revealed on October 26. There were however discrepancies in the times released. Tass reported the launch would be at 0323 GMT on October 29, while Radio Moscow said the launch would take place at 0324 GMT on October 29. The exact time was revealed after the launch was aborted; 0323:46 GMT.

Around the world the Soviet tracking network was in position, four research vessels in the Atlantic and Pacific Oceans and four satellite systems were ready to monitor the flight.

Regular television bulletins from the Baikonur Cosmodrome kept viewers informed on the preparations and on October 28 Soviet newspapers carried reports on the impending test flight.

Glasnost was making a bigger impact in the Soviet space programme then ever before. This was the first time the launch of a new Soviet manned spacecraft had been reported in advance of its first flight. The launch was to be shown live on Soviet television, if any thing went disasterously wrong the world would be watching.

Unfortunatly things did not go to plan, although the problem was a minor one the Soviets still suffered some embarassment. It was typical of the malfunctions that had repeatedly dogged the US shuttle.

The crew access arm contains an emergency escape system for the cosmonauts and carries equipment for accurately setting the onboard gyroscopes. For these reasons the arm is left in position until the last possible moment. At T-51 seconds a computer detected this arm had not fully withdrawn and for the first time in the history of Soviet space flight a launch was aborted electronically.

If the launch had gone ahead the rising shuttle would have hit the arm and certain disaster would have resulted.

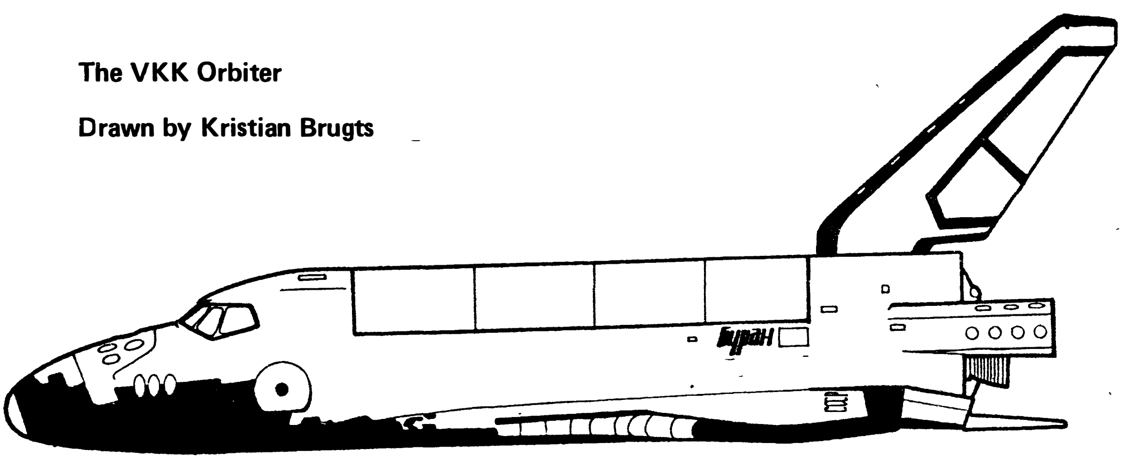
Tass announced: "The launch of the Soviet space transportation system Energia including the reuseable spaceship Buran, which was to take placé at 6:23 Moscow time, has been put off for four hours."

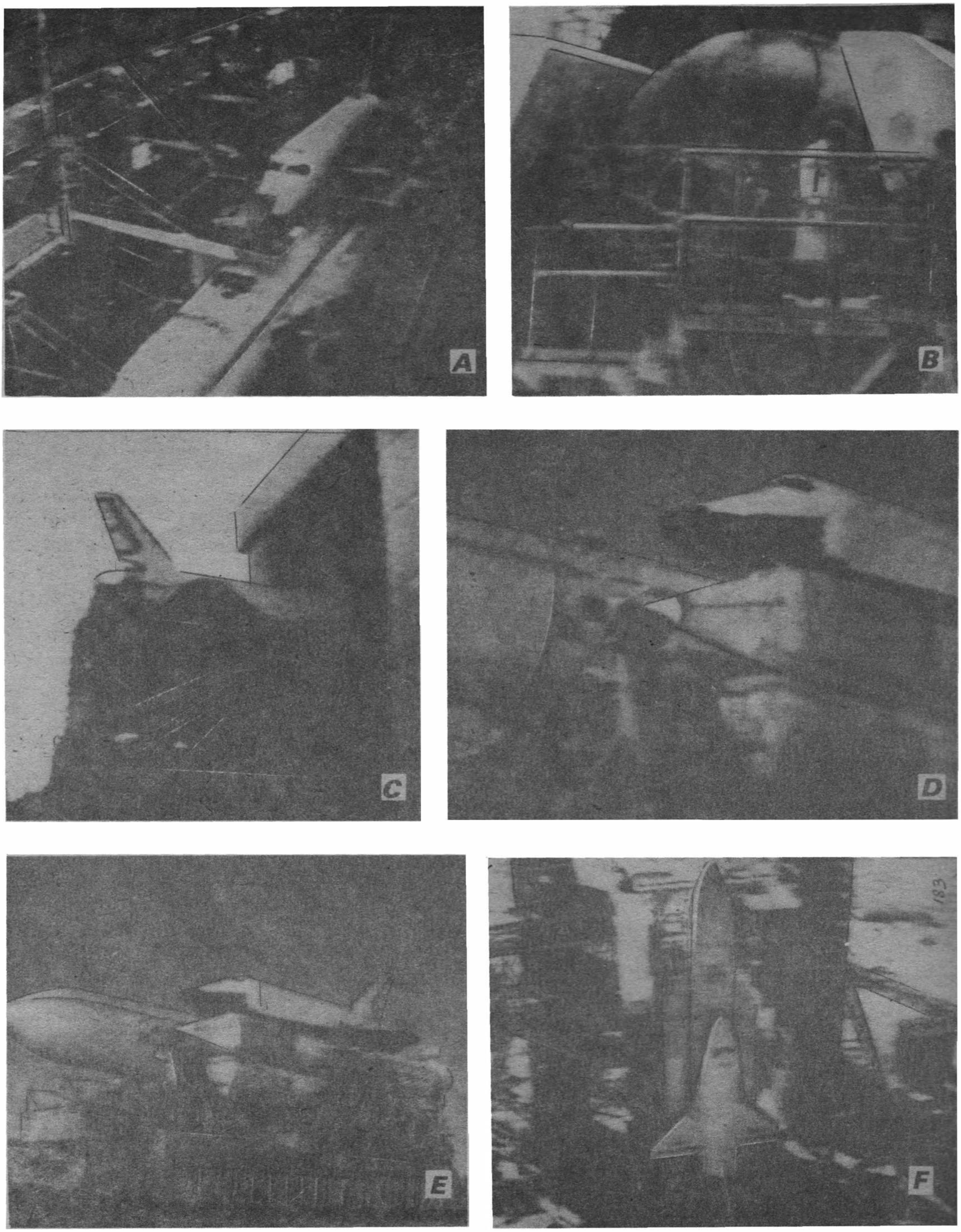
As the rescheduled launch time past Tass stated: "The launch of the Soviet reuseable spaceship Buran has been put off for an indefinite time."

Initially it was thought the launch would take place a few days later. But Air Major-General V.Y. Gudilin, head of the Cosmodrome Test Directorate, said the launch would "probably be after the November [7&8] holiday." He went on to say. "The time has gone by when launches were hurried to fit in with holiday dates. Haste in an important matter like space exploration is inadmissable." Later reports indicated a delay of up to twenty days. At the time of writing no new launch date had been issued.

The VKK Orbiter

Drawn by Kristian Brugts




A
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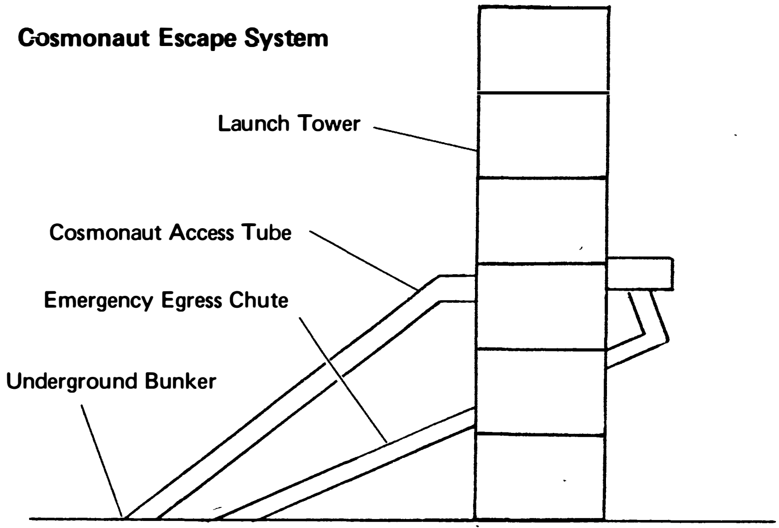
VKK Launch Complex

When the Soviet Union first released pictures of their shuttle much interest was in the launch pad with its futuristic looking tubular crew access arm. More details of this amazing launch complex have been revealed.



To the right of the shuttle is a service tower that appears on the Energia launch pad, this tower carries all the facilities for an Energia launch. To the left of the shuttle is the tower with the crew access arm. A third tower, which Soviet correspondent Mikhail Chernyshov refers to as "the Main Tower" rises to a height of 100 metres, the two others are slightly lower. This Main Tower appears in few Soviet photographs. Its purpose is to enclose the shuttle in maintenance ganteries. The Main Tower moves into position on rails.

Two shuttles and their Energia carrier rockets can be prepared simultaneously in the two specially constructed Assembly and Test Buildings. The vehicles are assembled horizontally and are lifted into the vertical position on the launch pad.

The VKK is assembled on the Mobile Launcher-Mating Unit which is hauled to the launch pad by four diesel locomotives on a double track. At the pad powerful machinery tilts the vehicle until it is vertical.

The launch pad used for the first Energia launch in May 1987 is known as the universal pad. It has the single right hand Energia service tower. This launch complex suffered major damage during the first Energia blast off, as a result the shuttle launch pad has been improved.

Huge pipes bring a deluge of thousands of litres of water onto the pad from two reservoirs located next to the service towers. In addition to cooling the ferro-concrete structure the water helps to prevent sound waves reflecting off the pad and damaging the ascending vehicle. In the event of a fire breaking out water, foam and inert gases (e.g. nitrogen) can be directed at the pad.

At the centre of the launch pad is a concrete flame pit sunk up to five storeys down. The VKK launch pad has three vents to remove Energia's rocket exhaust. The original Energia launch pad had just one of these vents.

Two tubes about three metres in diameter run from the crew access arm to an underground bunker. The upper tube is the route cosmonauts will take to the crew compartment. Special trolleys will carry the crew up the tube from the underground bunker to a spacious white room, from here they can enter the orbiter through the side hatch.

The lower tube which follows a much steeper angle to the access tunnel is an emergency egress chute for the cosmonauts. According to Soviet reports the escape from the orbiter to the underground bunker takes only 15 seconds.

The crew access arm is also thought to carry unbilicals, reports following the aborted launch attempt said the arm is responsable for ensuring the vehicle's gyroscopes are set precisely.

The shuttle countdown is under more computer control than that of any other Soviet launch vehicle.

Dr. V. Karashtin told journalists the system for the automated control of the launching complex has three levels that receive and issue more than 100,000 signals. The first level is directly connected with the rocket and is the master controller, the other levels function only upon receiving a signal from the first level.

The task of the computer system is illustrated by the fuelling process. To fill Energia's ten fuel tanks the system has to simultaneously operate more than four thousand actuators.

During fuelling of the huge booster the pad area is evacuated leaving the computer and a network of television cameras to monitor the process.

A: Buran and its Energia booster undergo final launch preparations within the Assembly and Test Building at the Baikonur Cosmodrome.

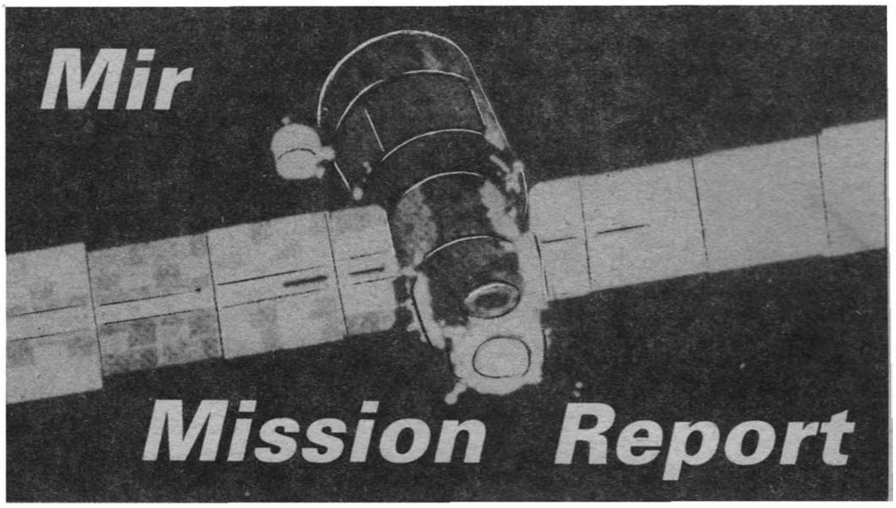
B: Soviet technicians work on an umbilical panel on Buran's rear bulkhead. Note the orbital manoeuvering thruster pods.

C: Energia and Buran emerge from the Assembly and Test Building atop the Mobile Launcher-Mating Unit. Note the umbilical connected to the rear bulkhead.

D: A close-up of Buran's forward section during its roll out to the launch pad. Note the manoeuvring thrusters are in exactly the same position as the US shuttle. The crew access hatch is just visible.

E: This photograph shows the massive transporter that carries the shuttle to the launch pad. Note the system for righting the vehicle on the pad, located at the aft of the transporter.

F: The shuttle arrives at the launch pad and is tilted into the vertical position, the machinery that performs this function is just visible behind the Energia booster. The crew access arm is in the withdrawn position. The pipes that carry a deluge of water to the launch pad are visible, as is the right-hand water reservoir. This overhead picture was taken from the 100m high main tower.



Spaceflight **correspondent** Neville Kidger **reports on the activities of the cosmonauts manning the Mir space station. His report includes the reentry problems encountered during the joint Soviet/Afghan mission**

Continuation of Work

Following the failure of their five hour 10 minute excursion into open space to try and replace the Kvant TTM X-ray telescope detector cosmonauts Vladimir Titov and Musa Manarov (call sign Okeans) spent the first few days of July resting and replacing their spacesuits and other equipment. On the ground preparations were underway for the next attempt to replace the detector. Manarov told TV viewers that some 70 per cent of the work needed to complete the job had already been accomplished. September was being tipped by western observers as the next most likely date for the second attempt to finish the work. But that month passed with no further EVAs being accomplished. It was later announced that the EVA would occur on October 20.

During the next weeks the work continued as routine, with the men conducting observations of the surface of the Earth both visually and with cameras. The many hours of observations and picture taking were devoted to studies of the territory of the USSR in the search for mineral deposits, farming and environmental protection.

During one televised exchange with a specialist at the Flight Control Centre the cosmonauts were told that the Soviet/Bulgarian cosmonauts had brought back about 150 pictures taken by the Okeans which were of a good or excellant quality. They showed ring structures around Lake Balaton in Hungary and gradations in water in Baku bay which were to be used in environmental studies.

Such results, and the conveying of them to the cosmonauts, echoed one of the points made by Vladimir Shatalov to the *Nedelya* newspaper in October 1987. In that remarkably frank interview the head of Star Town told readers that cosmonauts in space needed to know that their work was being put to use to enable them to endure the long stays in space better. The cosmonauts' boss also said that the Soviet space programme in general lacked "purposefulness and consistancy." He said that results of work done in space disappeared from view once returned to Earth and that a quicker turn around was needed between the conducting of an experiment, the analysis and use of its results and the development of follow-on experiments. "At this pace we won't set up orbital workshops and factories... by the year 2000," he said.

Shatalov had called for a speedier return of materials to Earth rather than having to wait for a manned ship every six months. The experience of the heavy Kosmos 1443, which returned 350 kg of materials to Earth in August 1983 from Salyut 7, "has been forgotten" he said.

The cosmonauts also conducted observations with the Kvant X-ray telescope battery and the Glazar UV telescope mounted on the module to study different areas of the sky as part of their on-going astrophysics programme. They used the Maria magnetic spectrometer regularly to study the flow of high energy charged paricles in the area of the Mir complex.

Regular medical checks were also made of the men, showing that they maintained their good health as the year-long flight progressed.

Progress 37 in Orbit

At 2113 (all times GMT) on July 19, the Soviets launched Progress 37, another of the series of unmanned resupply spacecraft based on the Soyuz design, from the Baikonur Cosmodrome. It docked with the rear port of the Kvant module at 2234 two days later. The men began to unload its cargo of food, mail, clothes and other consumables, the day after docking. The cargo ship delivered more items for the life-support system of the complex which require regular replacement. The installation of these items, such as air regenerators, takes up a large part of the cosmonauts' working time in orbit.

Also delivered were a new colour TV monitor and computer, a spacesuit which works without an umbilical cord connecting it to the station and some equipment to be used during the joint Soviet/French month-long mission due to start on November 21.

The Soviets reported that the windows of the complex had become covered in a layer of "dust" and advised Titov and Manarov that when they made another EVA they were to wipe them clean!

As July gave way to August the cosmonauts continued their Earth observations work and spotted forest fires in the Urals, southern Siberia and Soviet Far Eastern regions. Firefighters were despatched to the scenes of these outbreaks.

Refuelling of the complex by the cargo craft was begun on August 7, and continued for two days. The engine of the cargo ship had been used to correct the orbit of the complex which, on August 9, was reported to be: height 375 x 355 km; period 91.5 minutes; inclination 51.6 degrees.

Progress 37 was undocked from the complex at 0432 on August 12, and was deorbited to destruction, as planned, shortly afterwards.

Soviet/Afghan Flight

By August 15, Titov and Manarov had been in space for over 237 days. This moved them into second place behind Yuri Romanenko for a single space mission duration. The next week would see the continuation of astronomical work interspersed with Earth observations* and physical exercises, the Soviets said.

On the ground preparations were nearing completion for the second international flight of 1988 – that of two Soviet and one Afghan cosmonauts.

The agreement for the mission was signed in Moscow on February 11, 1988 and the original intention was to fly the mission in 1989 after the cosmonaut candidates had been through the usual year-and-a-half training cycle. However, because the Soviet Union was to begin withdrawing its 100,000 plus troops out of Afghanistan in mid-May the political situaton in Afghanistan for the 1989 date could not be guaranteed. Therefore, it is likely that the Soviets opted for a much earlier flight date to ensure that the regime of Afghanistan's present leader, Dr. Najibollah, was still in power during the flight which it had agreed to. Launch was set for August 29.

The Afghans originally examined 50 candidates for the flight and quickly narrowed these down to 12, then to eight. The final two candidates were selected after they had been examined in Moscow in January 1988. The two selected were both Russian-speaking Afghan Air Force pilots who had fought in the war:

Colonel Mohammad Dauran Ghulam Masum and Captain Abdol Ahad Mohmand.

Vladimir Shatalov said that the short time for training for the mission was made easier to cope with because the men knew Russian, having been trained at Soviet AF academies. In addition, Shatalov said, the Star Town Training Centre "now has vast experience in training crews for international projects."

On April 29, two crews were introduced to the press. The two Soviet commanders were Vladimir Lyakhov, then also the reserve for the Soviet/Bulgarian flight, and Anatoli Berezovoi. The crew was to feature

* Pictures taken by the cosmonauts are to be used as part of an annual remote sensing experiment conducted by the Soviet-bloc nations. The 1988 experiment is called Tien-Shan Interkosmos-88 and begun on August 11 in Tajikistan and Kirghizia. It was due to end on September 1. Countries taking part included Bulgaria, Hungary, Vietnam, the GDR, Poland, Romania and Czechoslovakia. Pictures from space are combined with ones taken from aircraft and samples from ground level in these studies.

two researcher cosmonauts instead of a flight engineer and an RC. Both the experienced Soviet commanders had trained to fly Soyuz TM ships solo as part of the "Rescuer" programme which would see a rescue mission to Mir should that become necessary.

The first researcher cosmonaut was a physician. The two selected were Dr. Valeri Polyakov, 46, who had served as a reserve cosmonaut for Soyuz T-3 and Soyuz T-10, and Dr. German Arzamazov, 42. Both had graduated from the Sechenov Medical Institute in Moscow and both held a degree of Candidate of Medical Sciences. Polyakov had begun preparing for space missions in 1972 after joining the Institute of Medical and Biological Problems in Moscow in October 1971.

The two Afghans, Dauran and Mohmand, were named in that order at the press conference, giving the impression that Dauran, at 34, was the prime choice over the 29 year old Mohmand.
(It was revealed Duran had an operation for appendicitis during the short training period.)

The mission would see the three men spend six days in Mir conducting experiments. The commander and the Afghan would then return to Earth leaving the physician on Mir to help the two Okeans with minor housekeeping tasks and also to monitor their health as they ended the long flight.

On August 10, the Soviets reported that the prime crew would be Lyakhov, Polyakov and Mohmand with the other three being the reserves. They had spent the previous week in tests of their ability to handle space equipment. The men were to be allowed three days off to be with their families before they flew to Baikonur on August 17 or 18. TASS spoke of the "telescoped" training cycle the Afghans had done.

In the week before the flight the Soviets showed unprecedented TV pictures of the assembly and testing of the Soyuz TM-6 spacecraft in the assembly hanger at the cosmodrome. Western journalists had seen the craft during the period leading up to the launch of the Phobos -1 Mars probe on July 7.

The spacecraft was rolled out to the launch pad on August 27, just two days before the planned launch. The Soviets said that the rocket would be launched at 0423 GMT on August 29. Lt-Gen Kerim Kerimov, the chairman of the State Commission which oversees the Soviet manned space programme said that the crews had passed medicals and that the prime crew would be confirmed on August 28. He also claimed that the Soviets had achieved 96 per cent "infalibility" in the operation of manned space vehicles and that the aim was perfection. They were words he may have regretted just over a week later!

(Kerimov also said that another Energia rocket "may" be launched in 1988. Rumours and reports from Moscow had been reporting a planned launch of the giant carrier rocket in June and August 1988 with the prototype unmanned version of the Soviet reusable spacecraft on it. Photos of the Energia/Shuttle combination on the pad were released by the Soviets to coincide with the launch of Discovery in the USA on September 29.)

The commission decided that the Lyakhov crew was the prime and the events leading to the launch, and the event itself, were shown live on Soviet TV.

Soyuz TM-6 in Flight

The Soyuz carrier rocket with the three man crew aboard was launched into clear blue skies at 0423 on August 29. Beforehand the Afghan cosmonaut Mohmand had read out a statement from the spacecraft which called for peace in his homeland. The Afghan government had announced a unilateral ceasefire with the Mujahedein guerrillas for the duration of the joint flight.

In his 1.5 kg personal allowance of baggage Mohmand carried a copy of the Koran, the Holy Book of Islam. He, and Dauran, had prayed with the book the night before launch.

Soyuz TM-6 was in orbit after about nine minutes of powered flight, the rocket having done its job. At 0920 and 0943 the spacecraft's engines were fired to correct the orbit for the first time. Another major firing the next day put Soyuz TM-6 into an approach trajectory for the Mir complex.

The docking with Mir/Kvant, at the Kvant's rear port, was uneventful and contact was made just before 0541 on August 31. Just after 0700 the visiting crew was welcomed by Titov and Manarov. After a warm reception and the reading of short statements to the TV cameras, Mohmand, who had probably not met Titov and Manarov before that day, read a solemn passage from the Koran. Clearly, the propaganda aspect of the flight was to be as important as the scientific one.

Scientific Programme

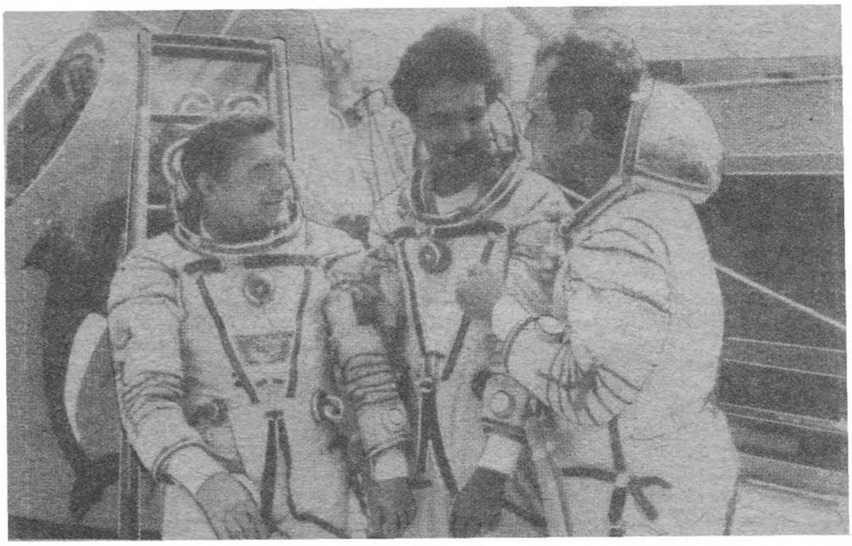
The science work for the six days of joint flight involved Earth observations and medical tasks. The short duration between the agreement of the flight and its realisation meant that no more experiments could be planned. The equipment used was either Soviet or Bulgarian, used in that mission's science programme.

The Afghans named the programme Shamshad (after an Afghan mountain) and it involved 24 separate aspects. Prime amongst these was the mapping of the territory of Afghanistan with the KATE-140 topographic camera which was a permanent feature of the Mir station. From Mir's height the camera took a picture with a coverage of 450 x 450 km with a ground resolution of 50 m. In addition the men used two spectrometers: the MKS-M and the Bulgarian Spektr-256.

The various subsections of the Earth observations programme were called Relief, Geology, Glaciers, Rivers and Lakes, Oasis, Vegetation, Cartography, Atlas and Survey.

Specifically, the photographs and other observations would cover the mountainous regions of the country in a search for oil and gas deposits and the low areas to study the land for soil erosion and subsurface water for farming uses. (One western observer said that because of Mohmand's Air Force background it was likely that he would be looking for the mountain retreats of the guerrillas.)

Mohmand reported that the conditions were good for the studies of his country, which he later described as "very beautiful" from the vantage point he was in.



The crew for the Soviet/Afghan mission during pre-flight training (left to right) Lyakhov, Mohmand and Polyakov. *Novosti*

The second part of the Shamshad experiment involved a series of medical tests on the Afghan cosmonaut's adaptation to weightlessness. These experiments involved the Soviet long-term research aim of characterising the process of adaptation to weightlessness. The experiments Statokinetika, Potentsial, Labrint, Prognoz, Opros and Son-K had all been performed before.

Dr. Polyakov had donated bone marrow before the launch, along with Dr. Arzamazov. These samples would be compared with samples to be taken from Polyakov when his flight ended.

Polyakov was later to admit to "something of a dissappointment" by the good adaptation to weightlessness shown by himself and his fellows. He put this down to good medical and biological preparation. His colleague on Earth expressed sympathy for Polyakov's disappointment but said he was happy that the process had passed so well.

One of the medical experiments, which has been standard for many years on Soviet orbital stations, involves the cosmonauts

filling out a questionnaire about their feelings, health, pulse and blood pressure. The main crew of the station completes this proceedure every two weeks and the visitors were no different. Even while Mohmand slept his brain patterns were being recorded on the Bulgarian Son equipment.

The main crew continued with their work during the short joint flight. This involved use of the Ruchei electrophoresis installation to separate and purify a batch of interferon. Mention was made of the Climate experiment where the men measured the luminosity of a star and its dimming as it set behind Earth's limb – a standard experiment to determine the optical density of the atmosphere – and other atmosphere study experiments which used the Syrian Bosra instrument.

Biological work involved studies of a group of fish which had been brought in a small aquarium by the visitors and studies of plants in a magnetic field in the magnetobiogravistat device. Cell cultures were being developed in temperature controlled cabinets.

Astrophysics observations with the X-ray telescope battery were also continued.

On September 2, Mohmand spoke with Afghanistan's leader and on September 3, all the men participated in a televised press conference where Mohmand once again appealed for peace in his homeland. The questions were read out to the men in Russian and Afghan by the reserve crew.

Returning Home...

TASS reported on September 5 that most of the work for the joint flight had been accomplished and that Mohmand had exchanged seats in Soyuz TM-5, the spacecraft that had brought the Soviet/Bulgarian crew in June and which he and Lyakhov would use to return to Earth.

Mohmand moved his seat to the flight engineer's position and stowed the film cassettes, computer discs and other items to be returned to Earth, including the aquarium, in the researcher's seat. This was done to distribute weight correctly in the small descent cabin.

To be returned also was an ampoule with the product of a Soviet/Australian experiment to obtain monocrystals of a flu virus antigen so that its properties and volumetric structure could be studied. The experiment had been started during the June joint flight.

In a TV discussion Polyakov said that he was looking forward to continuing the joint flight with the resident crew. Titov said that the visiting expedition had met its requirements in terms of training and operation. The visitors had displayed a great deal of humour which he contrasted with earlier crews; this had helped reduce the tension, he said.

At about 2000 on September 5 Lyakhov and Mohmand bade farewell to their three comrades and floated into Soyuz TM-5. They donned their launch-and-entry pressure suits and, at 2255, undocked the ship from Mir's front axial port, beaming stunningly clear TV shots as the craft separated. The planned landing time was announced as 0215, September 6.

At 2335 Soyuz's globe-shaped orbital module was cast off. This left the two men in the small descent cabin attached to the engine unit. This procedure was first used on the Soyuz T series spacecraft to save 10 per cent of the fuel needed to bring the spacecraft out of orbit.

The firing of the retro engine was scheduled for about 0125 on September 6 Just before Soyuz was in range of the tracking ship Nevel in the South Atlantic. The event is normally a totally automated one controlled by the craft's computer.

...But First a Problem

When Soyuz reentered the radio visibility zone of FCC, controllers were told that a problem had occurred. As Soyuz approached the terminator an infrared vertical sensor, which detects Earth's heat, was interfered with by the Sun's rays causing it to become "lost" and send incorrect commands to the computer. This inhibited the retrofiring. Switching to another sensor produced a similar situation and again the motor did not ignite. Lyakhov reported this situation to FCC.

"Emergency... The motor fired for 60 seconds... It switched off..."

Seven minutes after the first attempts the infrared vertical was reacquired and the computer issued commands to fire the rocket. However, by this time Soyuz had moved 3500 km further along its ground track. Lyakhov manually shut down the engine after three seconds when he realised that the spacecraft would land in China.

FCC staff assessed this situation and decided to fire the engine two orbits later for a landing at the Soviet back-up site.

The Soviets later said that the spacecraft could land at many sites worldwide and an international agreement would ensure aid for the cosmonauts and their repatriation with Soviet authorities.

FCC read up new coordinates for the next attempt and told Lyakhov to retain the information in the computer memory independent of the operation of the infrared sensor. Three hours after the first aborted attempt the FCC staff and reporters listened out for the results of the second try.

Lyakhov's voice was routed through a surface ship and a satellite. He called out: "Emergency...The motor fired for 60 seconds...It switched off...breach of the stabilisation regime..." Retrofire should have lasted 230 seconds.

Lyakhov reported that the engine fired at first for just six seconds, a fault later attributed to the programme for the automatic system's work not being amended promptly following the first malfunction. It appeared that the computer had used the back-up programme for the braking burn for the *approach* to Mir rather than the descent pattern!

Lyakhov then ignited the motor manually but the spacecraft drifted out of its proper stabilisation. The experienced cosmonaut was later to be criticised for not switching off the computer and waiting for radio contact to be reestablished before he proceeded. In the event the motor shut down yet again after 49 seconds.

Shortly after this Soviet TV played a recording which contained Lyakhov laughing, illustrating his good spirits. After a period of analysis Valeri Ryumin, an experienced cosmonaut and flight director said that the landing had been postponed for 24 hours. He told Lyakhov and Mohmand not to worry. "Nothing terrible has happened. The life support system is sufficient for 48 hours."

He then asked about food. He was advised there was none on Soyuz.

"And the emergency stores?"enquired Ryumin,

"There is some there, but why touch it? We'll manage," Lyakhov said.

"The ASU situation is worse."

The ASU is the Soviet acronym for the waste management system. The short duration pressure suits that the two men were wearing did not have any waste management facilities. Without the orbital module, which had been cast off, there was no way the two men could remove these suits for their bodily functions. When reporters later asked Lyakhov how the men managed he told them to work it out for themselves!

The men were to spend a day in the cramped confinement of the descent module where the internal temperature was just seven degrees C. Soviet officials were worried for the men – and their aquarium.

The reason for the delay of 24 hours was simple – the Soviets wanted to land Soyuz in the USSR after reprogramming the computer. For this the Earth had to turn on its axis. Members of the Kettering Space Observer Group heard streams of figures being read up to Lyakhov in the afternoon of September 6.

Meanwhile, in the west, TV and radio stations reported the delay as a major story and it stole the headlines. The men's temporary difficulties, whilst being a problem and being reported as such in the USSR, was interpreted by many western news media as a life-threatening situation. It was widely assumed that the men were "stranded" in orbit. (One banner headline proclaimed the men were "LOST IN SPACE" – they were not, of course, the Soviet ballisticans and western trackers knew exactly where the Soyuz was!)

The atmosphere created was one of crisis and, whilst some FCC personel admitted to worry and sleepless nights the Soviet reporting of the situation was measured so as not to cause alarm.

Finally Home

As western newspaper readers digested the men's problems with their breakfasts the drama of the return had already been played out in Kazakhstan.

At 0001 on September 7, on command from the automatic equipment, Soyuz TM-5's motor was ignited. After the required time the engine was switched off and the descent cabin and engine block separated. As the cabin with two men inside came through the atmosphere, veteran cosmonaut Vladimir Dzhanibekov told a reporter at FCC that the events of the previous day were not "dangerous" but that there were elements of risk at certain stages.

Dzhanibekov, who has flown five Soyuz missions, said a "blunting of vigilance" had been in evidence during the previous day and that some caution had been lost.

Flight director and ex-cosmonaut Vladimir Solovyov admited to "several hours of worry" during the events and said that the work to bring the two men home had been "extremely tense and measured – difficult work."

TV picked up the descent module of TM-

5 under its huge parachute against a dawn sky. The landing occurred in a field at 0050. A dust cloud was kicked up by the retrorockets of the module.

There was applause at FCC which could not see the events on TV. TASS said the landing occurred some 160 km south-east of Dzhezkazgan. It was just 10km from the newly-plotted target spot.

Five minutes after touchdown Lyakhov and Mohmand were being helped out of the cabin. In an impromptu interview whilst he was being examined, his face mopped and hair combed, Lyakhov conceded that it had been "tough" in the descent module for the extra 24 hours. He assured the pressman that there had been no threat of anything serious and the two had been in control of the situation.

Lyakhov said that such situations were part of their training but that on the ground the simulation ended after about 20 minutes and the men left the simulator. In space it had really lasted 24 hours.

Dr. Igor B. Goncharov, who was examining the cosmonaut said that despite the "emotional tension" Lyakhov's pulse was in the normal range.

Mohmand, sat alongside his commander, looked very calm. He said that the journey had not been too arduous despite the delay in landing. He felt that seven days in space was not long enough though.

In a brief interview, the deputy head of the USSR Search and Rescue Service, K.K. Subbotin, said the recovery had been "a bit more complicated" this time but the service had worked accurately and all zones had been tested. The service had recovered 78 people from spaceflights, he said.

Once the men were safely on Earth the inquest began as to the failure of the first day's attempts to reenter. US analyst James Oberg said that the "incredible haste" with which the Afghan flight had been planned and executed contributed to the failure of the infrared sensor. He ventured that it had not been programmed to expect a mid-summer encounter with the Sun's rays and that the two men had narrowly missed a too-steep reentry that would have seen them burned up in the atmosphere.

A comparison was made by Soviet reporters between the Soyuz 33 "Bulgarian spaceship" of 1979 and the Soyuz TM-5 "Bulgarian spaceship of 1988. Soyuz TM-5 had delivered the Soviet/Bulgarian visitors to Mir in June and had experienced difficulty in the approach phase when the Kurs approach guidance system showed errors. The computer used to calculate the September 7 reentry was a Bulgarian one.

Lyakhov later suggested that in future the Soyuz orbital module should be kept attached until after retrofire – as in "The good old days" – so that if a similar circumstance befell another crew they would be able to use that module to sleep in and perform their toilet functions. The module has a volume of 4 m^3. The descent module features 3 m^3 but is more cramped than that in reality because of the extra equipment crammed in for return to Earth.

Speaking at a press conference shortly after the landing deputy flight controller Viktor Blagov was grilled by Soviet journalists eager to find out who the guilty parties were. He replied, somewhat philosophically, "Life is to blame, a combination of circumstances."

Meanwhile for their courage and heroism on the flight the cosmonauts were awarded high Soviet honours.

Redocking Soyuz TM-6

Flight director Vladimir Solovyov reminded the world, shortly after the return of Lyakov and Mohmand that the flight was continuing in orbit. He said Soyuz TM-6 was to be redocked and a new freight craft was to be sent to the complex.

At 0105 on September 8, after the three cosmonauts had crossed over into it and sealed themselves in, Soyuz TM-6 was commanded to undock from the rear port of the complex. Under the command of on-board automatic systems the whole complex then rotated 180 degrees so that the front docking unit faced the Soyuz.

Titov then manually redocked with the front port at 0125 and the three men crossed back into the complex.

Progress 38 in Space

At 2334 on September 9, the Soviets launched the Progress 38 cargo spacecraft towards the complex. It docked at 0122 on September 12, at the rear of the complex.

The cargo ship delivered over two tonnes of supplies including some 300 kg of foodstuffs, including fresh vegetables and fruit, new scientific apparatus, equipment for the base unit of the complex, instruments and medical equipment and fuel and oxidiser for the propulsion system and air and water for the life-support system.

The complex was tracked by western sensors in a 337 x 363 km orbit with a 91.5 minute period.

The unloading of the cargo ship reportedly began on September 13 and was conducted along with astrophysical observations and medical checks over the next few days.

In their astrophysics work the men took yet more ultraviolet shots of constellations with the Glazar telescope and also obtained more X-ray observations of the supernova.

Further materials processing work was conducted to produce extra-pure substances and improved semi-conductor materials which could not be produced on Earth. The Biryuza unit was used to study the formation of spatial structures during chemical oscillatory reactions.

The men also found time to study the Earth's surface, photographing forests and steppe regions and spotting fields of plankton in the oceans of the world.

Refuelling of the complex was begun on September 27. Two days later the three cosmonauts sent a message of congratulations to the five American astronauts who had flown the Space Shuttle Discovery into orbit that day in the first shuttle flight since the Challenger accident 32 months earlier. For 19 of those months – since early February 1987 – the Soviets had maintained a permanent manned presence in space.

The Soviet/French mission has been delayed to November 26 to allow President Mitterand to be present at the lift-off. The EVA is now scheduled for December 12.

Titov and Manarov will return to Earth at the end of this joint mission. Volkov will be left with his flight engineer Sergei Krikalyov and Dr. Polyakov for a mission expected to last six months. It will see the launch of two modules to the station according to current reports.

Mir Space Walk

Cosmonauts Vladimir Titov and Musa Manarov made a daring space walk to repair the Anglo-Dutch TTM telescope. Their first attempt in June ended in failure (See *Spaceflight* October 1988, p.396).

During the spacewalk the cosmonauts tested a new space suit that can operate independently, past suits have required an umbilical connected to the space station. The suits have a body section of aluminium alloy and arms and legs of elastic material. The new type of suit will allow cosmonauts to make space walks of six to seven hours in length compared with five hours offered by the previous suits.

Because the new suit can function without an umbilical it provides the cosmonauts with greater freedom of movement. The suits will be used with the manned manoeuvering units the Soviets have developed.

On October 20 at 0659 GMT the Mir hatch was opened. The Cosmonaut Doctor Valeriy Polyakov remained sealed in the decent module of Soyuz TM-6 as the rest of the complex had been depressurised.

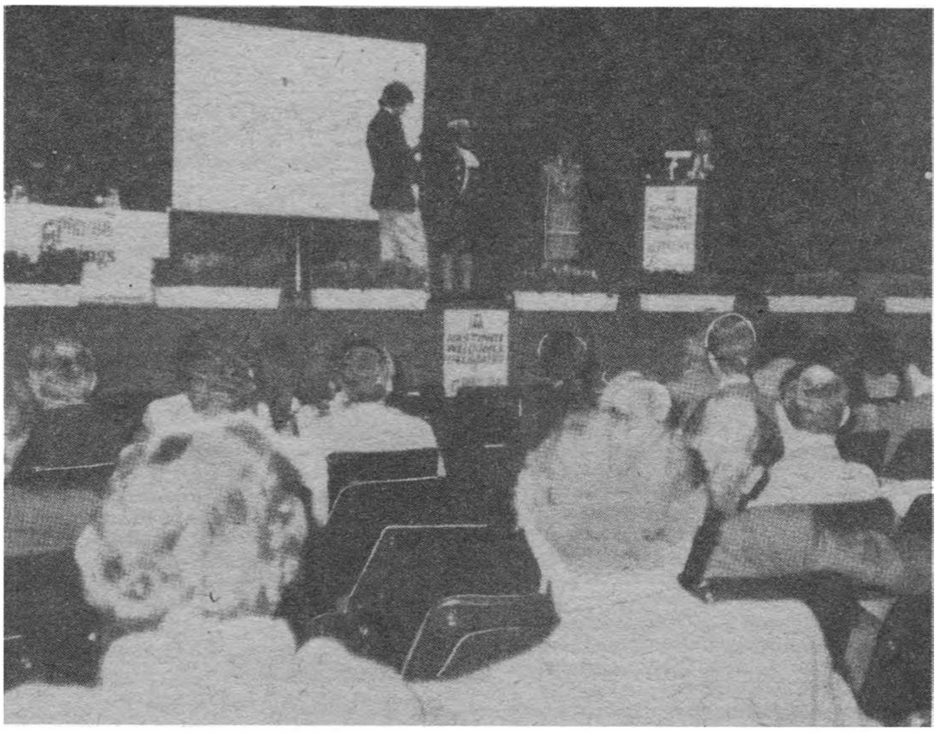
The cosmonauts made their way down the Mir complex until they reached the Kvant module docked with Mir's rear port. Their task was to replace a faulty detector on the TTM telescope. The new detector was designed to make it easier for an on orbit repair. Large handles and a new fastening were added making it easy for the cosmonauts, with their bulky space gloves, to install the unit.

The faulty detector however was not designed for on-orbit repair. The cosmonauts were carrying a variety of tools to remove a capture ring that prevented them replacing the detector during their first spacewalk. The tools were specially constructed for the spacewalk and were delivered to Mir onboard Progress 38.

The new tools proved their worth – the faulty detector was removed at the first attempt. The replacement detector was installed an hour earlier than expected.

After completing their main task the cosmonauts carried out further work on the exterior of Mir. An anchor point for use during the Soviet-French space walk was attached to Mir's hull. And an aerial for communications between the station and radio amateurs was installed. This aerial can also be used as a back-up communications system.

The duration of the space walk was 4 hours 12 minutes.



The **SPACE '88** opening ceremony.

SPACE '88 AT HASTINGS

The Society's **Space '88** weekend opened with a Civic Reception on Friday evening. The Mayor of Hastings, Cllr Sandy Barr, and members of the town council were in attendence to welçome the **SPACE '88** delegates officially. A buffet , cabaret and dance all contributed to an enjoyable evening.

One of the highlights of the Society's **SPACE '88** meeting in Hastings was the presentation of a plaque and discovery photograph of Asteroid No.3817 named "Len Carter" in honour of the Executive Secretary of the British Interplanetary Society.

Eleanor Helin, joint discoverer with S.J. Bus of this minor planet, made the presentation at the **SPACE '88** Banquet on October 1. The asteroid was first observed with the 1.2m United Kingdom telescope on June 25, 1979 in Siding Spring Australia. But this large chunk of "space rock" has only just been named because of the need to plot its orbit accurately, this was accomplished after 30 further observations.

Mr. Carter, who has been Executive Secretary of the British Interplanetary Society since 1945, was proposed for this honour by Dr. W.I. McLaughlin and endorsed by Dr. R.L. Staehle, both of the Jet Propulsion Laboratory in California.

The citation on the plaque reads:

> "For more than 50 years his efforts have been the basis for the constructive role of the Society in space advocacy, education and international communications."

It is believed that this is the first time a British non-astronomer has been honoured in this way.

Following the presentation the diners at the Banquet were entertained by speeches from Patrick Moore CBE, Alan Bond and David Hughes.

Throughout the weekend an impressive array of international speakers brought the delegates up to date with the latest space developments.

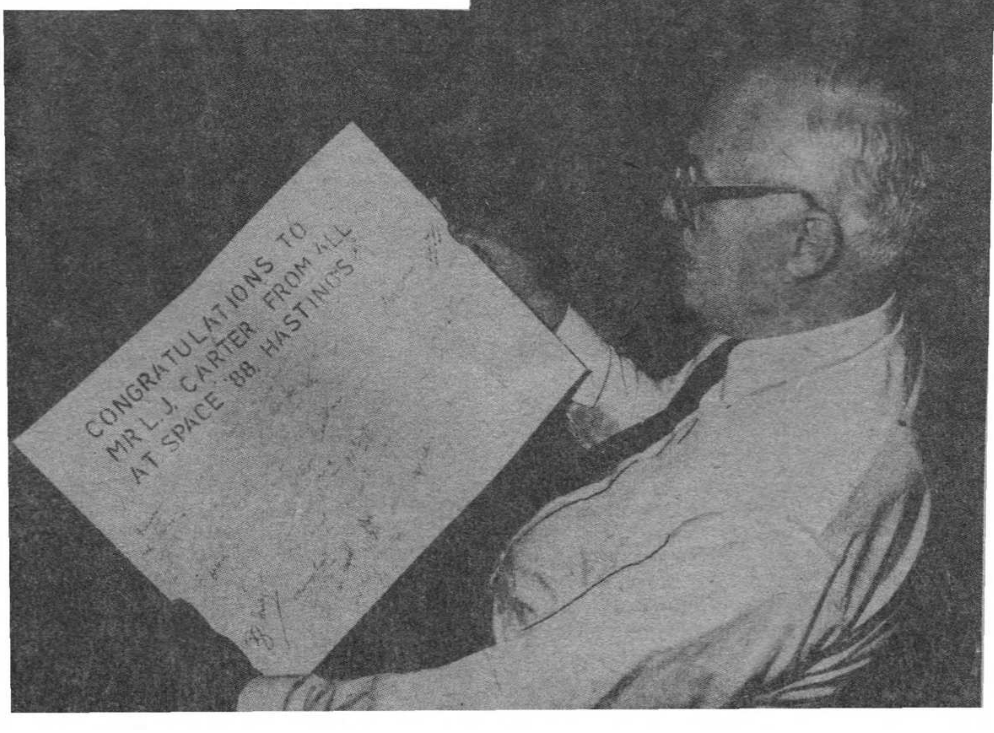
The speakers and their subjects included: Dr. W.I. McLaughlin (A Philosophy of Space Exploration), Mr. R. Gibson (Britain in Space: A Philosophical Approach), Dr. L. Suid (Space & Mankind: The Writer's View), Mr. P.J. Conchie (Aerospace Vehicle Operations in the 21st Century), Mr. A.T. Lawton (The Future Role of Trans-Atmospheric Vehicles and Making Semi-Conductors in Space), Mr. P. Norris (Information Technology for Future Space Systems), Mr. D. Webber (The Future of Satellite Mobile Communications), Dr. D. Llewellyn-Jones (Space Coolers), Mr. H.J.P. Arnold (Planet Earth and the Future of Remote Sensing), Dr. M.J. Fowler (Space Biology and Medicine: Into the 21st Century), Dr. I. Bekey (The Human Exploration of Space), Dr. R.C. Parkinson (Cities on the Moon?), Dr. G.E. Hunt (Some aspects of a Mars Base), Dr. D.W. Hughes (The Importance of Sample Retrieval from Comets), Dr. R. Reinhard (A Review of Future Comet Missions), M.J. Fogg (First Steps to Terraforming the Planets).

SPACE '88 Banquet: Eleanor Helin speaks before presentation of the plaque to Mr. L. J. Carter. Those seated are, from left to right, Dr. W. I. McLaughlin, Mr. L. J. Carter, Dr. Patrick Moore and Mr. G. W. Childs President of the BIS.

ORGANIZED BY THE
SPACE '88
HASTINGS
SEPT 30 – OCT 2
BRITISH INTERPLANETARY SOCIETY

Bill Childs, Society President, presents the Mayor of Hastings, Councillor Mrs Sandie Barr, with a framed copy of a star map reproduced from J. Bayer's classic Uranometria.

A unique photograph of three people, each having an asteriod named after them. (Left to right) Len Carter, Eleanor Helin, and Patrick Moore.



Len Carter, BIS Executive Secretary, receives a card of congratulations signed by all those involved with Space '88.

SPACE '88 Opens Door To the Future

Everything augured well for an outstanding success for the Society's meeting, **SPACE '88**, held on the weekend of October 1. Not only was the weather and location near perfect, with excellent hospitality provided by the Corporation of Hastings, but the future for man's progress into space looked bright with the shuttle Discovery successfully launched into orbit and the Soviet shuttle unveiled during the preceding few days. The Society's President, Mr. Bill Childs, caught the mood of the occasion in his opening address by referring to the timeliness of the meeting in the light of current events which gave added significance to 'The Exploration of the Solar System' – the session topic for day two of the meeting.

On day two, participants were not to be disappointed and it was a privilege for the Society to be providing the occasion for the unveiling by Dr. I. Bekey of NASA's plans for extending the space infrastructure from orbital space stations to lunar bases and the surface of Mars by the 21st Century.

The immense enjoyment of the occasion experienced by participants has since been expressed in many letters to the Society:

> I would like to say how very much I enjoyed **SPACE '88** last month, the lectures and speakers being of the usual high standard of previous years. I am now looking forward to attending SPACE '90 as well as the Society's November one-day meeting in London on the Space Infrastructure.
>
> P.A. Heard, Cumbria

> Everybody that I talked to seemed to like Hastings very much. The weather helped naturally – but it did seem to be 'friendlier'.
>
> H.J.P. Arnold, Havant

> I have just returned from the **SPACE '88** conference at Hastings and would like to express my thanks to the BIS staff for the impeccable organisation of the event. BIS conferences are always a little like swans, sailing serenely on the surface but paddling furiously underneath!
>
> Sally Lord, Cranfield

Our grateful thanks are indeed due to the BIS staff for their exceptional efforts both during the long planning stage of the meeting and for making their services available during the weekend of the meeting, so providing such a memorable event.

Society Speed-Up

The steps that the Society is taking to improve its office facilities has brought a favourable response from members. Society Fellow Mr. P.A. Heard writes:

> I was pleased to read in October's edition of Spaceflight magazine about the Society's acquisition of a Fax machine and a new telephone exchange. This is a good move in the right direction in this age of information technology, and I would certainly support any efforts to obtain more items of this type of equipment in the future.

November's Spaceflight has since announced to members the introduction of a computerised system for processing member services. We are pleased to report that the system is proving to be invaluable in dealing with the volume of 1989 membership renewals now flowing into the Society. We welcome member's keen interest and support for the Society's continuing development.

Boost To Extension Appeal

The Society's Extension Appeal, standing at September 1, 1988 at £27,884, has received an added boost by virtue of a Council decision to augment funds by transferring from Society reserves a contribution of £20,308 which had been earmarked for building purposes. This now brings the total up to £48,192.

Members letters and donations continue to provide encouragement and support for the planned extension to the Society's premises:

> I would like to order two Spaceflight binders and enclose a donation to the Buildig Appeal.
>
> Widnes, Cheshire

> Please find enclosed a cheque for which is a donation to the Building Appeal Fund. I do not want a receipt or any other reply to this letter and so I have decided not to include a stamped addressed envelope. Good luck!
>
> Liverpool

Although we are now well over the half-way mark towards our estimated £80,000 target, inflation continues to take its toll and the cost of building work, as with the cost of property generally, is escalating rapidly and makes it all the more necessary to reach our goal as quickly as possible.

Society Renewals For 1989

Our thanks to the many members who have promptly responded by returning their membership renewal forms for 1989. Prompt payment is more than ever necessary this year owing to the introduction of the computerised dispatch system which will automatically omit sending magazines to those who are late in settlement and will not reinstate dispatch arrangements until payment is recorded. Members are urged to respond as soon as possible if they have not done so already. Any member who has not yet received a Renewal Notice should contact the Society.

By special arrangement, the Society can accept cheques expressed as payable in U.S. dollars provided that these are payable in the U.S.A. It is regretted that dollar cheques payable elsewhere cannot be accepted as these attract additional bank charges that reduce the realizable value and cause problems by creating balances which lead to additional costs.

It should also be noted that Postal Money Orders from the USA and Canada can be cashed in the UK only if the amount payable is expressed in sterling.

MEETINGS DIARY

LIBRARY

The Society Library is closed until further notice due to continuing building work at the Society's HQ.

30 November 1988, 6.30-8.30 p.m. — Visit

SCIENCE MUSEUM

A special visit of Society members to the Science Museum in South Kensington. The programme will provide an opportunity for a leisurely view of the Space Gallery and to see vintage space film footage.

The fee will be £6.00 per member to cover the cost of a buffet with wine which will be provided.

Advance registration is necessary as the party will be limited in number. Guests will be allowed if space is available. Forms are available from the Executive Secretary.

Society meetings, unless otherwise stated, are held in the Society's Conference Room, 27/29 South Lambeth Road, London SW8 1SZ. Meetings are restricted to Society members unless otherwise stated. Tickets should be applied for in good time by writing to the Executive Secretary at the above address enclosing an SAE.

4 January 1989, 7.00-8.30 p.m. — Lecture

ROCKET MAIL

A lecture by James Goddard, Curator of Space Technology of the Science Museum. Three decades before satellite communications became a reality, rocket technology promised another means of communication over substantial distances. Before the 1930's, 'Rocket Mail' would, it was argued, result in publicity and funds for contemporary rocket pioneers. Was it ever a pragmatic approach to communications or, as some suggest, merely a fund-raising exercise resulting in a colourful and lucrative market for the philatelist?

Admission is by ticket only. Members should apply in good time by enclosing a stamped addressed envelope.

Boosters Performed Well

Post-flight inspections of the STS-26 solid rocket motors (SRMs) have borne out the integrity of redesign efforts, with the disassembled field joints and case-to-nozzle joints showing good performances.

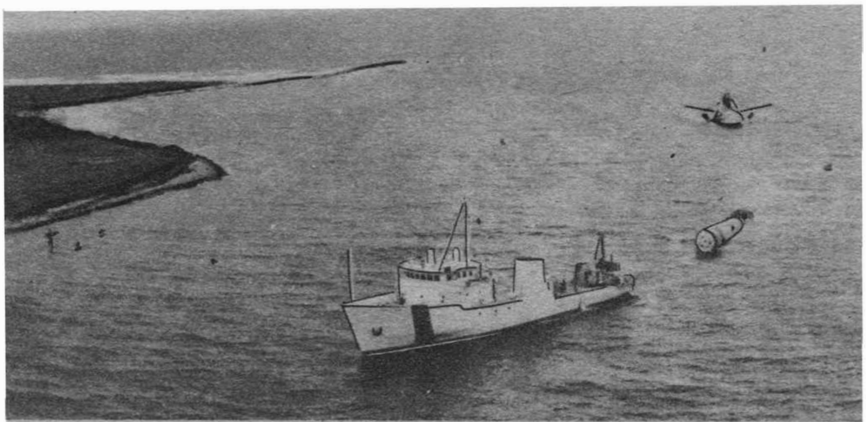
"The field joints looked really good, with no blow-by, no hot gases to any of the O-rings, and the J-seal performed well," Engineer Rod Lofton said. "There is nothing in the field joints that is preventing us from flying STS-27."

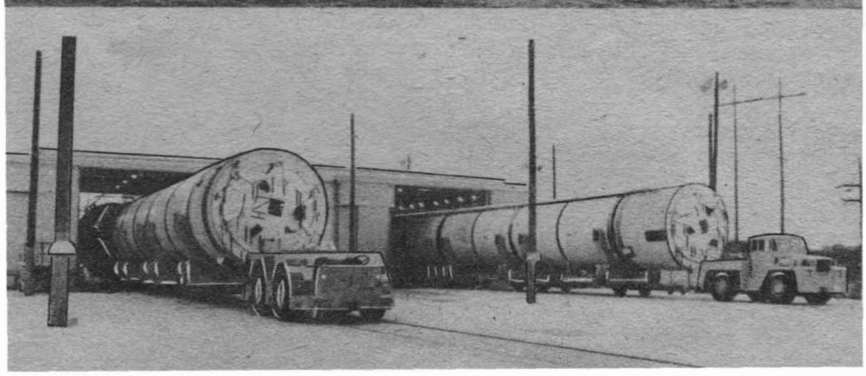
The redesigned case-to-nozzle joint also performed well, Lofton said. No evidence of seal damage, blow-by or pressure reaching past the wiper O-ring was found.

"We are very pleased and encouraged by the results," Lofton added.

The factory joints will not be fully inspected until the boosters are shipped back to Morton Thiokol, but a preliminary look indicated excellent results.

The two boosters splashed down about 120 nautical miles downrange of Kennedy Space Center, both within nine nautical miles of their respective recovery ships. The two ships, the *Freedom Star* and the *Liberty Star*, began towing the SRMs back a little more than six hours after launch. They arrived in port the following afternoon.



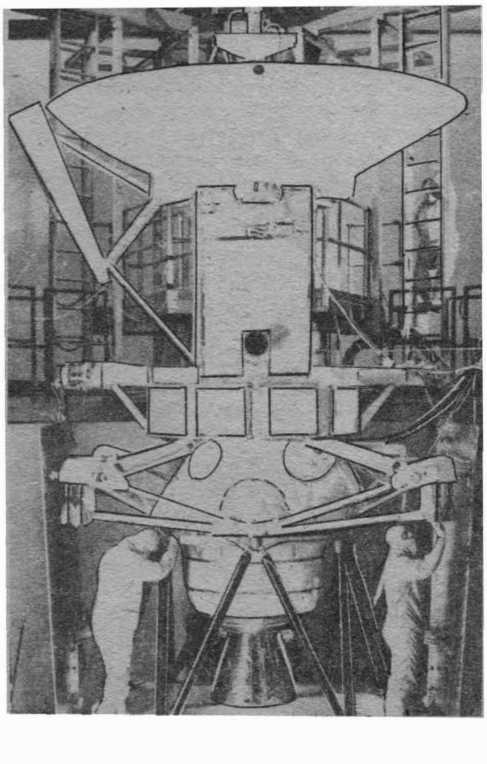


(Top) The STS-26 Solid Rocket Boosters are returned to port.
(Bottom) The STS-26 boosters are towed into a hanger for disassembly. NASA

As the field joints were disasembled throughout the week, nothing unusual was found, and the three O-rings in each joint were labelled in "excellent condition." However, the impacts of the boosters' splash downs were evident on the exterior of the field joints.

The cork insulation surrounding each joint contained between one and three liters of seawater. Several other torn cables and sheared bolts were found along the length of the boosters, and the external tank attachment ring on the right-hand booster was bent. But the findings are not a flight safety issue, Lofton said.

"There was some thermal protection system damage and structure damage due to water impact, but nothing awfully unusual," Lofton added.



Fire Hits Magellan

The Magellan Venus probe suffered a small but intense electrical fire, damage was minimal and it is thought there will be no impact on the April 1989 launch date.

The fire occured at the Spacecraft Assembly and Encapsulation Facility at the Kennedy Space Center on October 17. The fire was caused when a technician made a wrong connection which short circuited a test battery.

The fire was put out within 1 minute and the damage was limited to the test battery and harness which are part of the ground equipment. However, Magellan's insulation blankets were damaged and some 'sooting' occurred.

The Magellan probe before transfer to the Kennedy Space Center.

The Magellan team will work overtime to make up the lost time caused by the fire. The repair work is not expected to affect the April 28, 1989 launch date.

Hauck Steps Down

STS-26 Commander, Rick Hauck has announced he will not seek another space flight.

Hauck told journalists at a post-flight press conference. "You have got a lot of people waiting in the wings to take other peoples places... I think it's time to let some others have a chance at the left-hand [commander's] seat." He explained." It's nice to finish a stage of your life on a high note."

Hauck went on to say his future plans were uncertain, but he would be looking at other positions available within NASA or in the Navy.

Shuttle Fleet Status

SPACE SHUTTLE

Atlantis OV-104

At the time of writing Atlantis was undergoing final launch preparations for its classified Department of Defense Mission, STS-27.

Atlantis was rolled over to the Vehicle Assembly Building (VAB) during the night of October 22. The following day the orbiter was attached to its sling in readiness for mating with the External Tank (ET) and Solid Rocket Boosters (SRB). Mating was achieved on October 24 at 7:15 pm (local time). The Shuttle Interface Test was conducted over the next few days to check the connections between the spacecraft and the Mobile Launch Platform.

After mating, engineers from Rocketdyne, manufacturers of the Space Shuttle Main Engines (SSME), began measuring an injector faceplate in Atlantis' main engine No. 3 to ensure the plate had not warped. The check was instigated following concerns about a popping noise heard during tests of other main engines, an Indication of the same type of noise was heard during test of Atlantis' No. 3 engine.

The popping noise during the engine tests had indicated a warped faceplate at the bottom of an oxidiser preburner in other engines.

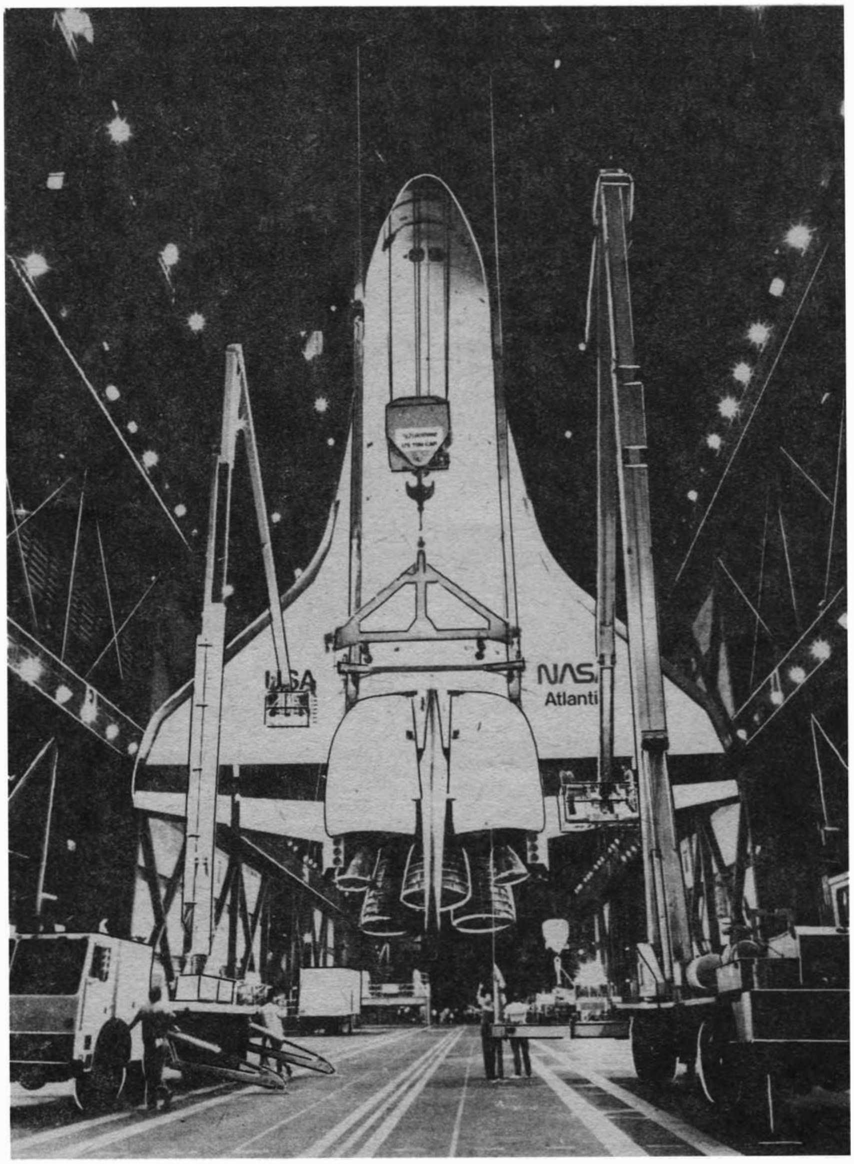
Rocketdyne engineers evaluated the data from the injector plate on engine No. 3 and the determined measurements were within specifications and acceptance for flight.

The planned roll out of Atlantis on October 31 had to be postponed when a piece of wire was discovered between a bolt and a washer that connects the ET to the Orbiter. As a safety measure Atlantis was re-connected to its safety sling and the bolt loosened to enable the removal of the wire.

Roll out to pad 39B finally occured on November 2, with first movement at 1:23 am. The weather conditions remained good during the 4.2 km journey. The Shuttle arrived at the pad at 8:00 am and was 'hard down' on its pedestals at 9:15 am. The Orbiter Access Arm was moved into position and during the afternoon the Rotating Service Structure enclosed the shuttle. Later that night the Orbiter was powered up.

The orbiter was loaded with hypergolic fuel for its Reaction Control Thruster and Orbital Manoeuvering System and fuel for the Auxilary Power Units on November 5 & 6.

The Countdown Demonstration Test was scheduled for November 14, the STS-27 crew will board Atlantis on the pad for a rehearsal of the countdown procedures. On November 15 & 16 the Flight Readiness Review will take place.



Discovery OV-103

Discovery is in Bay 1 of the Orbiter Processing Facility at the Kennedy Space Center undergoing preparations for its next mission, STS-29, currently scheduled for February 1989. The OASIS instrumentation has been removed from the payload bay for analysis. The Ku-band antenna will also be removed to determine the cause of the problems encountered with the system during STS-26.

The suppliers of the Orbiter's flash evaporator system has been studying the system's in-flight troubles.

A leak was discovered in No. 1 main engine. The leak is located between the main combustion chamber and the nozzle. The engine will be replaced before STS-29.

Columbia OV-101

Preparations continue in the Orbiter Processing Facility for the launch of Columbia on STS-28 a classified DoD mission.

Atlantis is lifted into the vertical position prior to mating with the shuttle stack. *NASA*

New Shuttle Computers

The first complete ship's set of an updated version of the Orbiter's five onboard flight computers, more than twice as powerful but half the size of those now flying, is being tested at the Johnson Space Center (JSC) and may fly in 1990.

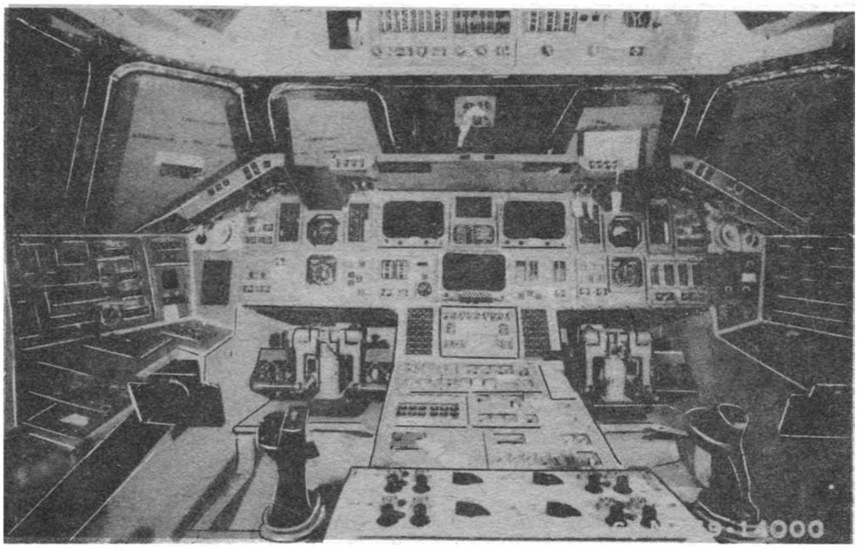
Every flight control function aboard an Orbiter is initiated by or through the five onboard General Purpose Computers (GPCs), including the movement of all aerodynamic surfaces and control of the main engines. "The computers now flying were designed in the 1960's, using 1960s' technology," explained Ned Trahan, chief of the Data Processing Section at JSC. "The new ones have 1980s' technology."

The rapid advance of technology during that period is evident in the appearance of the new GPCs now in the JSC Avionics Engineering Laboratory (JAEL). The new computers are half the size of the current Orbiter GPCs, made up of a single unit as compared to two units for the current computers.

And the new GPCs operate two to three times as fast have about two and a half times the memory capability and weigh half as much as those now flying. "They also have an Error Correcting Code; you could have a failure in one of the memory chips and the code would automatically correct the data," Trahan said.

It all adds up to what will be a tremendous boost in reliability and performance, plus an open road for innovation. The current GPCs operate at 80 per cent of their capability during periods of highest activity. Using the same software, those same periods will push the new GPCs to only 40 per cent of their capacity.

"We want to run the old software in the new machines with a minimum of changes. It's proven reliable," Trahan said. "But eventually we'll modify it over a period of time to take advantage of the extended capabilities."



A view of Discovery's flight deck- the three computer displays are clearly visible. *NASA*

Development of the second-generation GPCs began in 1983, but the race with the rapid evolution of high technology never ends. "You can see that from development to machine takes a long time," Trahan said. And if designers began at square one on development of third-generation GPCs today, the result would be even more impressive when completed in the 1990's.

Improved integrated circuits cut down the size of the new GPCs, and instead of the iron core memories in the current flight computers, the new ones have a Complementary Metal Oxide Silicon (CMOS) memory.

IBM, manufacturer of both the current GPCs and the new GPCs, began delivery of the actual flight-types to JSC in February. The JAEL had been working with pre-production prototypes of the computers since 1986, refining the design and operations.

Now the JAEL has six GPCs actually designated for flight, and they differ from the prototypes very little except in their parts. Prototypes were built with off-the-shelf, commercial hardware; flight GPCs are built with high-reliability, space-qualified components.

"With the actual flight units, and the first flight set of five, we're now doing what we call burning them in," Trahan said. "It's a process where we put as many operating hours on them as we can, hoping that any weak components in the system will fail." JAEL workers plan to put at least 500 hours on each GPC.

While the flight computers are burning in, the prototypes are being used in simulated fights via a link between the test bays in the JAEL and the high-fidelity Orbiter simulator in the Shuttle Avionics Integrator Laboratory (SAIL). So far, the new GPCs have lived up to their reputation.

At least 19 more of the second-generation GPCs will be delivered to the JAEL, enough to outfit four Orbiters plus a spare flight set. The lab should continue to receive about one new GPC a month, Trahan said.

TRW to Develop X-Ray Observatory

NASA has announced that TRW Inc. has been selected for final negotiations leading to the award of contracts for extended definition and development of the space-based Advanced X-Ray Astrophysics Facility (AXAF).

The development contract will include a mirror development phase and a priced-option for spacecraft development and completion of the observatory. Exercise of the option by NASA will require congressional approval and will be based upon the successful fabrication of the largest of six mirror pairs to the required resolution. The proposed cost for the contracts is approximately $508 million.

The facility will be the third in NASA's series of space-based great observatories, following the Hubble Space Telescope and the Gamma Ray Observatory into orbit in the mid-1990's. These observatories, as well as the Space Infrared Telescope Facility which is to follow the X-ray observatory, will permit simultaneous, complementary observations of astrophysical phenomena over different wavelengths of the spectrum.

The objective of this project is to develop a high-quality, X-ray telescope to be used by the international scientific community in conjunction with NASA for an operational period of 15 years.

The observatory will be designed for on-orbit maintenance as required to extend its life and to upgrade its scientific capability. The X-ray telescope will be used to gather data to expand our knowledge of quasars, black holes, the geometry and mass of the Universe.

Good News for Hubble

The launch of the Hubble Space Telescope has been brought forward to December 1989.

Delays with a Department of Defense shuttle mission have allowed NASA to switch this military payload with the Hubble Space Telescope. The telescope will now be launched by Discovery on December 11, 1989 and the DoD mission will be flown by Atlantis in February 1990.

Before the Challenger accident the Space Telescope was due for launch in August 1986. It was then re-scheduled for November 1988, then June 1989, then February 1990 and with this latest change has moved forward by two months.

Spaceflight has reproduced the original shuttle manifest on the next two pages, the news of the payload switch came to late to include in the schedule.

New Shuttle La

NASA has issued an update to the Space Shuttle flight schedule which reflects current planning through to STS-75 in September of 1993. The manifest of launch dates and payloads is for planning purposes, firm payload assignments are made during the formal integration process approximately 19 months prior to launch.

The Hubble Space Telescope launch date has been delayed seven months due to the delayed launch of STS-26, the orderly flight buildup rate in 1989, the need to preserve important Defense Department (DoD) missions, and the need to maintain the planetary launch windows, for the Magellan Venus radar mapper, the Galileo Jupiter mission, and the Ulysses investigation of the Sun and its environment.

The DoD mission on Columbia's first flight has been moved from February to July of 1989 which results in later launch schedules for all other Columbia flights with the exception of the March, 1992 flight of the United States Microgravity Laboratory-1. This flight will be the first step in extending Shuttle mission durations beyond nine days.

The planned launches support the Commercial Space Initiative which was announced with the National Space Policy on February 11, 1988 and includes the Industrial Space Facility as a fully reimbursable payload and the Spacehab middeck extension, consistent with the August, 1988 NASA/Spacehab agreement.

1989

STS-29, February 18: Discovery will deploy the TDRS-D satellite and carry the SHARE heat pipe experiment and the SSBUV solar backscatter ultraviolet experiment. A five man crew will fly this five day mission.

STS-30, April 28: Atlantis will launch the Magellan Venus probe during its four day flight with a crew of five.

STS-28, July 19: Columbia will fly a DoD payload with a five man crew.

STS-33, August 10: Discovery will carry a DoD payload.

STS-34, October 10: Atlantis will launch the Galileo Jupiter probe during its four day flight with a crew of five.

STS-32, November 13: Columbia will deploy the Syncom IV-5 satellite and retrieve the Long Duration Exposure Facility with a crew of five during a five day flight.

STS-36, December 11: Discovery will fly a DoD mission.

1990

STS-31, February 1: Atlantis will deploy the Hubble Space Telescope with a crew of five on a five day mission.

STS-35, March 1: Columbia will carry the ASTRO-1 astronomical payload and the Broad Band X-Ray Telescope (BBXRT) on a nine day flight with a crew of seven.

STS-37, April 5: Discovery will deploy the Gamma Ray Observatory (GRO) on a four day flight with a five man crew.

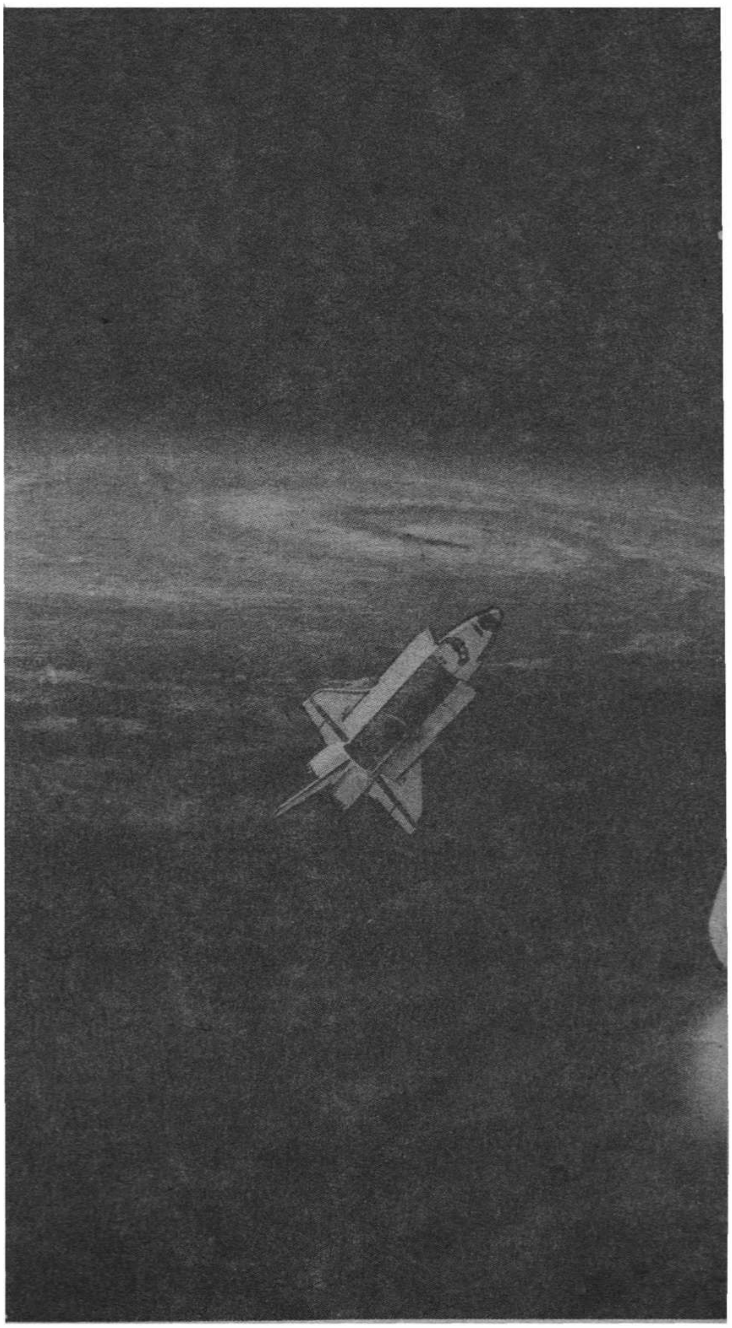
STS-38, May 10: Atlantis will be launched on a DoD flight.

STS-40, June 7: Columbia will carry the Spacehab Life Sciences SLS-1 payload during an eight day flight with a crew of seven.

STS-39, July 19: Discovery will carry the CIRRIS, Infrared Background Signature Survey (IBSS), and Teal Ruby payloads with a crew of seven on a seven day flight.

STS-41, September 10: Columbia will carry the Starlab payload on a seven day flight with a crew of seven.

STS-42, October 5: Atlantis will launch the Ulysses spacecraft during a four day flight with a crew of five.



An artist's impressio.. of one of the highlights of the 1989 shuttle schedule— the

STS-43, November 8: Discovery will deploy the TDRS-E satellite during a four day flight with a five man crew.

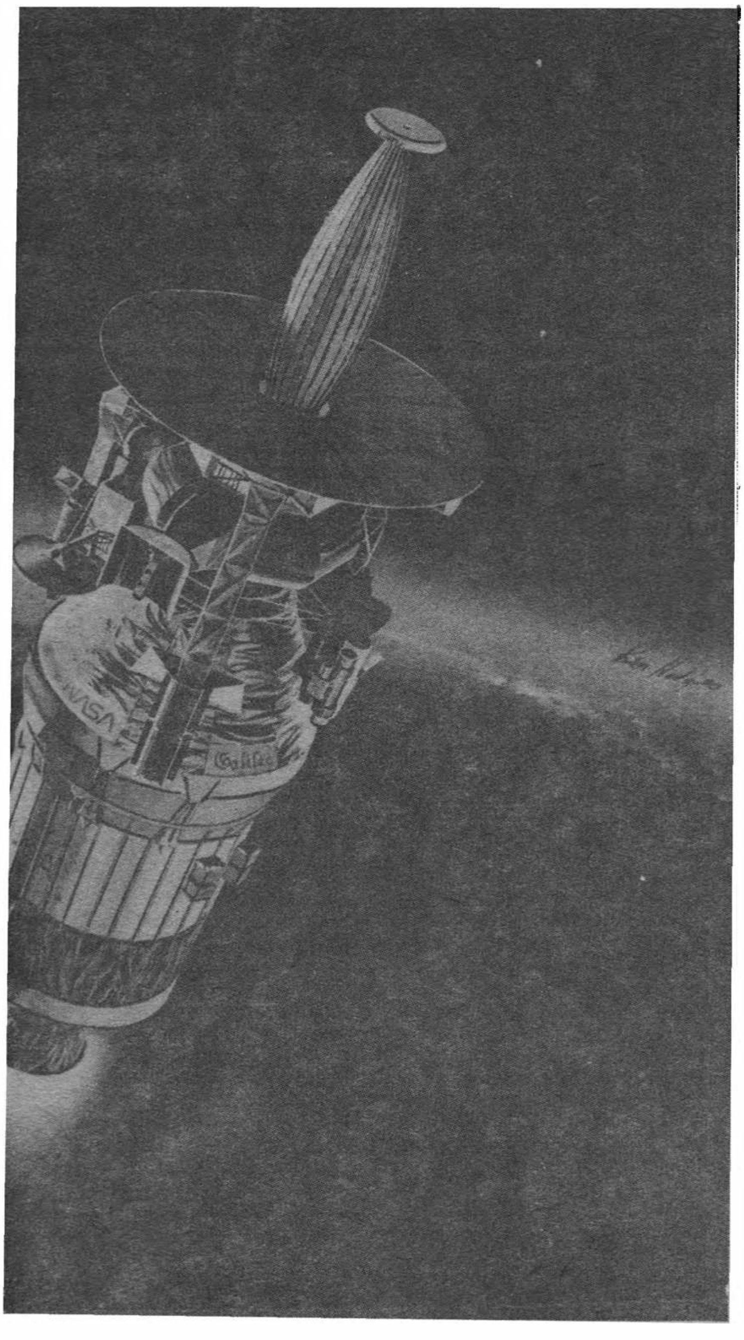
STS-44, December 20: Columbia will carry the Atlas-1 Spacelab payload with a seven man crew on a nine day flight.

1991

STS-45, January 31: Atlantis will deploy the Global Positioning Satellite GPS-1 and the Tethered Satellite System TSS-1 during a seven day flight with a crew of seven.

STS-46, February 28: Discovery will fly a DoD mission.

ıunch Manifest



eployment of the Galileo probe by an IUS upper stage. *NASA*

STS-47, April 11: Columbia will carry the International Microgravity Laboratory IML-1 on a nine day flight with a crew of seven.

STS-48, May 2: Atlantis will deploy the Global Positioning Satellite. GPS-2 and the Eureca-1 satellite and carry the Wide Angle Michelson Doppler Imaging Interferometer (WAMDII), on a seven day flight with a five man crew.

STS-49, July 11: Columbia will carry the SL-J Japanese Spacelab payload on a seven day mission with a crew of seven.

STS-50, August 15: Atlantis will carry the Spacehab-1 middeck extension and deploy the LAGEOS-1 and Inmarsat-1 satellites during a seven day flight with a crew of five.

STS-51, September 26: Discovery will deploy the Upper Atmosphere Research Satellite (UARS) during a five day flight with a five man crew.

STS-52, December 2: Columbia will carry the S/L-D2 Spacelab with a crew of seven on a nine day flight.

STS-53, December 23: Discovery will carry the ASTRO-2 astronomical payload and retrieve the Eureca-1 satellite during a seven day flight with a seven man crew.

1992

STS-54, February 27: The replacement orbiter; currently designated OV-105, will make its first flight and carry the Shuttle Radar Laboratory payload SRL-1 on a seven day flight with a seven man crew.

STS-55, March 30: Columbia will carry the United States Microgravity Laboratory USML-1 with a seven man crew on a flight planned to extend beyond nine days.

STS-56, April 23: Atlantis will carry the Shuttle High Energy Astrophysics Laboratory SHEAL-2, deploy the Geostar-1 satellite, and deploy and retrieve the Orfeus experiment platform during a seven day mission with a crew of seven.

STS-57, May 14: Discovery will carry the microgravity payload USMP-1 and deploy the Advanced Communication Technology Satellite during a seven day flight with a crew of five.

STS-58, June 11: OV-105 will carry the Atlas-2 payload and deploy a Satcom Communications Satellite on a seven day flight with a seven man crew.

STS-59, July 2: Columbia will carry the life sciences Spacelab SLS-2 with a crew of seven on a flight planned to extend beyond nine days.

STS-60, July 30: Atlantis will deploy the first element of the Industrial Space Facility ISF-1 with a five man crew during a five day flight.

STS-61, August 20: Discovery will fly a DoD mission.

STS-62, September 17: OV-105 will carry a DoD payload.

STS-63, October 8: Columbia will carry the IML-2 microgravity payload on a flight planned to exceed nine days with a crew of seven.

STS-64, October 29: Atlantis will carry the second Spacehab Middeck extension and will deploy the Geostar-2 satellite during a seven day flight with a crew of five.

STS-65, November 19: Discovery will deploy the TDRS-F satellite with a crew of five on a five day flight.

STS-66, December 17: OV-105 will fly a DoD mission.

1993

STS-67, January 14: Columbia will carry the Atlas-3 and CRISTA payloads on a flight planned to exceed nine days with a crew of seven.

STS-68, February 11: Atlantis will deploy the second element of the Industrial Space Facility ISF-2 on a five day flight with a five man crew.

STS-69, March 18: Discovery will carry the second Shuttle Radar Laboratory SRL-2 on a seven day flight with a seven man crew.

STS-70, April 8: OV-105 will carry the USMP-2 microgravity payload and deploy the Eureca-2 Platform during a seven day flight with a five man crew.

STS-71, May 13: Atlantis will carry a DoD payload

STS-72, June 17: Discovery will deploy the Geostar-3 satellite and retrieve the Delta launched SFU satellite on a five day flight with a five man crew.

STS-73, July 15: Columbia will carry the microgravity laboratory USML-2 with a crew of seven on a flight planned to exceed nine days.

STS-74, August 5: OV-105 will carry the Spacehab-3 and the Aeroassist Flight Experiment (AAFE) payloads during a seven day flight with a crew of five.

STS-75, September 9: Atlantis will carry gravity probe GP-B1 ande deploy the Inmarsat-2 on a seven day flight with a five man crew.

Roelof Schuiling

SATELLITE DIGEST – 217

Robert D. Christy
Continued from the November 1988 issue

A monthly listing of satellite and spacecraft launches, complied from open sources. The heading to each launch gives the name of the satellite, its international designation and its number in the NORAD catalogue. Launch times are given in Universal Time and are accurate to about five minutes except where marked with an asterisk, where the time is to the nearest minute as announced by the launching agency.

COSMOS 1958, 1988-60A, 19320
Launched: 1142, 14 July 1988 from Plesetsk by C-1.
Spacecraft data: not available.
Mission: Possibly electronic intelligence gathering.
Orbit: 373 x 412 km, 92.42 min, 65.84 deg.

PROGRESS 37, 1988-61A, 19322
Launched: 2113*, 18 July 1988 from Tyuratam by A-2.
Spacecraft data: Soyuz derived design, having a near-spherical supplies compartment carring a rendezvous radar tower, a covered liquids tank section and cylindrical instrument unit containing batteries and a combined rocket motor/attitude control system. Length 7.5 m (including the docking unit), maximum diameter 2.2 m and mass around 7000 kg.
Mission: Carried equipment and consumable supplies to the resident crew of Mir. It docked with Kvant's aft-facing hatch at 2234 on 20 July. On 12 August at 0832, it undocked and then re-entered the atmosphere following retro-fire.
Orbit: Initially 187 x 256 km, 88.87 min, 51.62 deg then by way of a 235 x 319 km transfer orbit to an orbit of 343 x 347 km for docking with Kvant's rear port.

COSMOS 1959, 1988-62A, 19324
Launched: 2228, 18 July 1988 from Plesetsk by C-1.
Spacecraft data: Cylindrical body with domed ends, enclosed in a solar cell covered drum with length and diameter both about 2 m. A 5 m long boom supports a metal weight to provide gravity gradient attitude control. Additional control is probably by spin-stabilisation which also takes care of heat regulation. The mass is around 700 kg.
Mission: Navigation satellite.
Orbit: 958 x 1006 km, 104.80 min, 82.96 deg.

INSAT 1C, 1988-63A, 19330
Launched: 2313*, 21 July 1988 from Kourou by Ariane 3.
Spacecraft data: Three-axis stabilised, box-shaped body, approx 1.5 m each side. Power is provided by a single solar panel, counterbalanced by a boom. The overall span is 19.4 m, and the mass 550 kg (excluding fuel).
Mission: Combined communications and meteorological data-collection platform. A power-supply problem means that the radio-transponders are not operating at full capacity.
Orbit: Geosynchronous above 93.5 deg East longitude.

EUTELSAT 1-F5 (ECS 5), 1988-63B, 19331
Launched: 2313*, 21 July 1988 from Kourou by Ariane 3.
Spacecraft data: Three-axis stabilised, box-shaped body approx 2.2 x 2.2 x 2.4 m. Power is supplied by a 13.8 m span solar array. The mass is 700 kg (including station-keeping propellant).
Mission: European communications satellite.
Orbit: Geosynchronous above 13 deg East longitude.

METEOR 3 (2), 1988-64A, 19336
Launched: 0503, 26 July 1988 from Plesetsk by F-2.
Spacecraft data: A cylinder with a pair of Sun seeking solar panels at right angles to the centre of the body, and an Earth pointing sensor array at one end. The length is probably about 5 m, diameter 1.5 m and mass around 2000 kg. Stabilisation is by the use of momentum wheels.
Mission: Meteorological and remote sensing satellite.
Orbit: 1186 x 1209 km, 109.43 min, 82.56 deg.

COSMOS 1960, 1988-65A, 19338
Launched: 1122, 28 July 1988 from Plesetsk C-1.
Spacecraft data: Not available.
Mission: Military satellite used as a calibration target for ground-based radars.
Orbit: 473 x 512 km, 94.48 min, 65.85 deg.

COSMOS 1961, 1988-66A, 19344
Launched: 2104, 1 August 1988 from Tyuratam by D-1-e.
Spacecraft data: Probably similar to the Gorizont satellites, being a stepped cylinder with a dish aerial array at one end. Electrical power is provided by a pair of rotatable solar panels at right angles to the body. Station keeping is by the use of gas jets, and three-axis stabilisation is achieved by momentum wheels. The length is about 5 m, maximum diameter 2 m, and the mass around 2000 kg.
Mission: Communications satellite providing continuous telephone, telegraphic and television links both within the USSR and aboard. It may also be providing tracking support to low-orbit satellites.
Orbit: Geosynchronous above 14 deg West longitude.

CHINA 23, 1988-67A, 19368
Launched: 0730*, 5 August 1988 from Jiuquan by CZX-2 (Long March 2).
Spacecraft data: Satellite with a recoverable capsule, length around 7 m and diameter around 2.5 m, and mass around 2 tonnes.
Mission: International micro-gravity experiments payload. The return capsule was recovered in Sichuan Province of China on 13 August.
Orbit: 206 x 313 km, 89.70 min, 63.02 deg.

COSMOS 1962, 1988-68A, 19372
Launched: 0925, 8 August 1988 from Tyuratam by A-2
Spacecraft data: Based on the Vostok manned spacecraft and consisting of a spherical, camera carrying re-entry module supported by a conical instrument unit containing batteries, control equipment and a rocket motor system. A 2 m diameter, 0.5 m deep, cylindrical, supplementary instrument package may be carried at the forward end. The overall length is about 6 m, maximum diameter 2.4 m and the mass is between 6 and 7 tonnes.
Mission: Military photo-reconnaissance, recovered after 14 days.
Orbit: 231 x 285 km, 89.71 min, 70.02 deg.

MOLNIYA-1 (73), 1988-69A, 19377
Launched: 2353, 12 August 1988 from Plesetsk by A-2-e.
Spacecraft data: Cylindrical body with a conical orbital adjustment motor section at one end. The opposite end of the vehicle carries communications aerials and a 'windmill' of six solar panels set in a plane at right angles to the main axis of the body. Stabilisation is by the use of momentum wheels. The length is about 4 m, the maximum diameter about 1.6 m, and the mass around 1800 kg.
Mission: Communications satellite providing telephone, telegraphic and television links through the 'Orbita' system both within the USSR and aboard.
Orbit: Initially 584 x 40757 km, 736.86 min, 62.85 deg, then lowered to 582 x 39796 km, 718.23 min, 62.87 deg to ensure daily repeats of the ground track.

New Hermes Escape System Proposed

OHB System in cooperation with Autoflug and British Martin Baker has proposed a new Hermes escape system concept to Aerospatiale, CNES and ESA. Called Hercules, the concept is for individual encapsulated seats for the space plane. Writes Theo Pirard.

Manager of OHB System Dr. Manfred Fuchs explained: "We presented our proposal in late August and we are now evaluating the positive reactions from MBB, prime contractor for the Hermes escape module, and from Aerospatiale, prime contractor for Hermes overall design. Our main problem is that this proposal has come a little too late. However there is still a chance our system will be considered for the final configuration of Hermes."

The current Hermes design has a crew cabin that can be jettisoned, called the Crew Escape Module (CEM). A final decision on the Hermes escape system will be made in spring 1989.

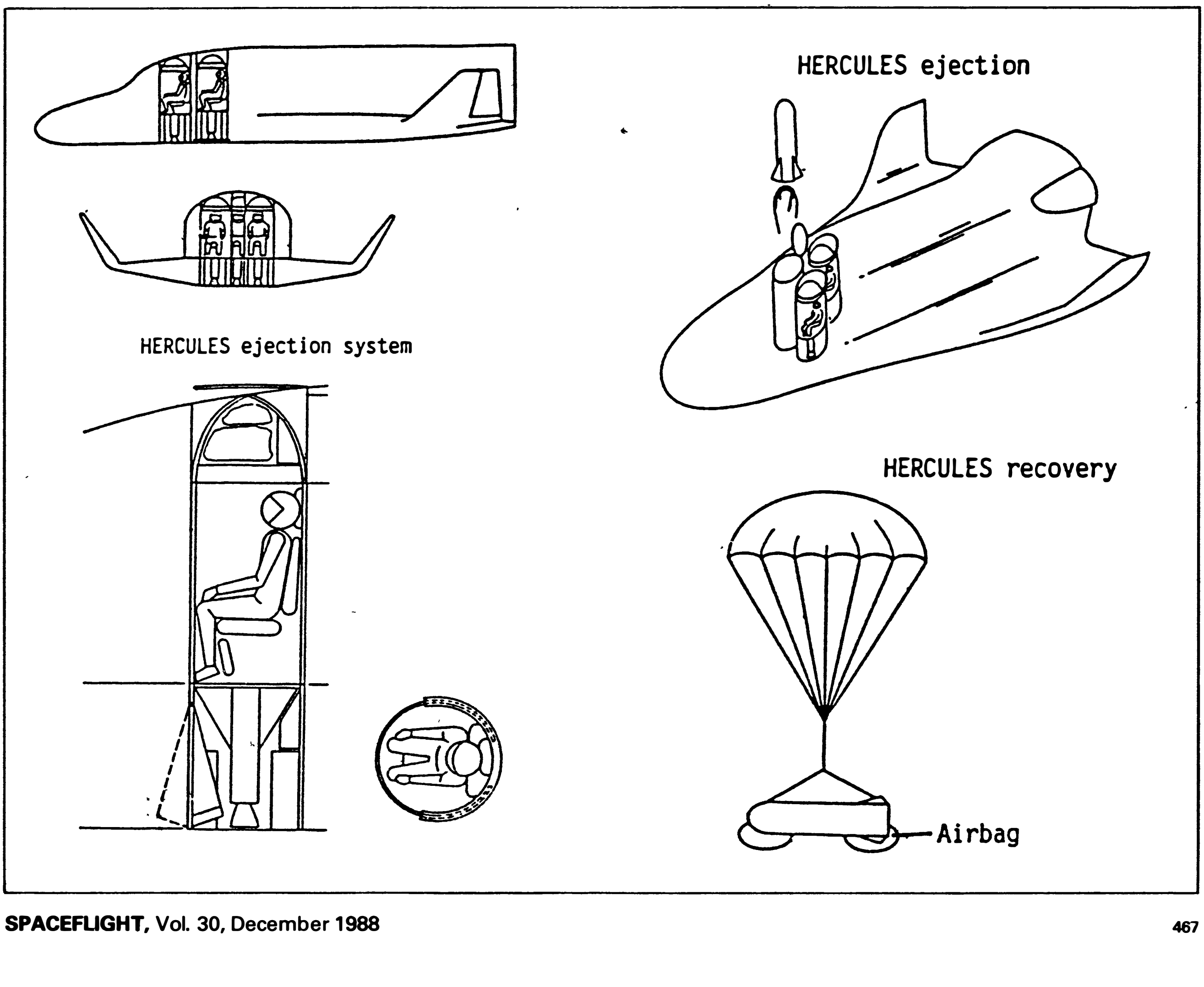
H.P. Nguyen of Aerospatiale is responsible for the CEM. He said: "No problems have been discovered which would invalidate the initial CEM concept. However, efforts are being made to lower the spaceplane overall mass. In this context, investigations on alternative systems are being actively pursued."

Dr. Fuchs of OHB System explained. "The Hercules concept is derived from our successful Mikroba capsule which is recoverable from an altitude of 40km. We have made feasibility studies to develop this capsule as an ejection seat for high-speed operations. Each Hermes astronaut will be encapsulated on an ejection seat equipped with a solid rocket, this ejection seat can be used very easily by closing the doors of the capsule...Within three seconds, it is propelled far away from the plane." He went on to detail the five main advantages of Hercules:

- Simplicity – with three fin-steerable capsules which can function very quickly and simultaneously.
- Mass economy – because each ejection capsule will weigh 300-400 kg; the total system will represent a handicap of 1 tonne, compared to CEM which will have a mass of 3 tonnes.
- Cost economy of the individual capsules, compared to the complex systems required for the CEM.
- Feasibility which can be demonstrated on a Hermes mockup.
- Physiological and psychological impact, because the ejection seat can be operated individually and in the right direction, to help the astronaut with the effects of acceleration.

The Hercules concept will cost for its development some 50 MAU (Million Accounting Units), while the CEM is estimated to cost 400 MAU.

Dr. Fuch plans to propose the use of the Hercules system on the United States National Aero-Space Plane (NASP).



Discovery

America Back in Space

Sir, The following are my thoughts on the STS-26 launch, written an hour or so after watching it on television.

Two years eight months one day. It has been a long time since that freezing morning. All that time it has been the cold winter of doubt. Now, suddenly, on a fall morning hope and fear mix. There are delays on this morning of course. That was expected, but that does not make it any easier. Finally the launch team decides all is ready to face the unknown. The countdown clock begins turning backwards from T - 9:00 minutes. The minutes and seconds tumble one after another. At about T - 1:21, the voice of mission control announces there will be a hold at T - 31 seconds due to problems with cabin pressurization. The nightmares loom. And then, as the clock passes the one minute mark, the hold is cancelled. It is time.

The familiar ritual begins: "15 - 14 - 13 - 12 - 11 - 10 - We're go for main engine start - 7 - 6...." The main engines ignite, the red flames billow out followed a moment later by the clear exhaust as they reach full power. They do not flicker and die. The count continues: 3 - 2 - 1 - 0. It is as if time has accelerated, rushing on like an irresistible force and the world has been contracted to the image on a television screen. The Solid Rockets roar to life. The commitment has been made, the ties with Earth have been broken and a Phoenix arises from the ashes.

Through tear-stained eyes, the Discovery is seen climbing, clearing the tower and smartly turning downrange. There is one more milestone to pass, one more call still to be made. After just over a minute the words are said: "Discovery, go at throttle up". There is a momentary pause and Discovery responds: "Roger, go". A minute later the two SRBs separate, their defiant roar now silent. The orbiter continues on, driven by the main engines. And then eight minutes 31 seconds and an eternity after lift off, the engines are shut down. In one direction, the blue and white Earth; in the other, the perfect blackness of space.

The great adventure begins again.

CURTIS PEEBLES
California, USA

Eye-Witness Account

Sir, I witnessed the launch of STS-26 from the roof of a three-storey building in Cocoa, about a dozen miles from the launch site; my wife witnessed it from downtown Winter Park, about forty-five miles west of the site.

As the clock counted down past T-30 seconds I began to eagerly scan the north-eastern horizon. About two hours prior to launch I had seen a tethered blimp in the area, apparently used to measure the baulky high altitude winds.

I saw no smoke at main engine ignition, but saw the shuttle almost immediately after Hugh Harris announced that it had cleared the tower. The white orbiter and SRBs mounted to the brownish ET were quite distinct. As Discovery went through its roll I could, through 7 x 50 binoculars, make out the black tiles at the orbiter's nose, tail, and leading wing edges, the windows, and a smudge I knew was the American flag. The detail would have been better, however, had I not been shaking with excitement!

I was surprised to see that the flame from the SRBs was a very bright, almost solid, orange colour. I had been led to believe it was white. Apparently television is overwhelmed by the brilliance of the flame, and photographic film cannot capture the colour.

Frustratingly, the shuttle ducked in and out from behind relatively low-altitude, puffy, white clouds. From our vantage point clouds blocked our view of SRB separation, though one of those present, viewing through 20 x 80 binoculars, claimed to have been able to see the SRBs falling away after separation. The shuttle very obviously dipped downward as it headed downrange.

It was exciting to be in a crowd, watching the shuttle climb, forgetting to breath and cheering as the many milestones on the way to orbit were passed.

My wife was able to see the launch from a street in downtown Winter Park. In the Orlando area it is traditional – if one takes notice of launches at all – to watch ignition and clearing the tower on television, then duck outside to see it rise in the east. She saw a sharp spark of orange flame and the white trail, and could make out the generally triangular white and brown shape of the shuttle stack. Clouds did not interfere with her view of SRB separation.

A few minutes after the shuttle passed from view everyone in Cocoa could hear a distant crackling roar as the sound reached us, carried on a wind from the north. It did not

sound too unlike a conventional airliner. It has to compete with the noise of what must have been every police car and fire truck siren in town being sounded in celebration. Shortly after that there was a kind of sustained oscillating vibration which seemed to move from one side of the sky to the other. The folks in the Orlando area heard nothing.

Cocoa was decked out in green ribbons commemorating the return to space – they were a project of the local chamber of commerce – and was surprisingly quiet. Most of the spectator traffic congregated on the beaches. Florida Road 520, leading west toward Orlando, was packed up as far as the eye could see within an hour of launch, and the State Police had to close the east-bound lanes of Florida 50, leading into Orlando, and make them west-bound.

I took advantage of the time I spent waiting for the traffic to clear to try a "Discovery Special" – a steak sandwich – in a local restaurant.

DAVID S.F. PORTREE
Florida, USA

Martian Calendar

Sir, Thomas Gangale's article, "The Lost Calendars of Mars" (***Spaceflight***, July 1988, p.278), makes some interesting points about the most suitable calendar for a Martian colony. however, in the early days of a Martian colony, before it becomes fully self-supporting, I am sure that the clock will be of far greater importance than the calendar. Colonists will certainly need a time system adapted to the situation on Mars.

The fictional scientists created by Robert Forward (***Spaceflight***, September 1988, Correspondence), require that the terrestrial second should be retained. This requirement has merit, for the second is a fundamental unit of measurement by which other physical units are defined. My solution to the problem of obtaining a logical and practical time system for use on Mars, while retaining the standard second would be to divide the Martian day (sol) into 25 hours, each hour into 50 (Martian) minutes and each minute into 71 (standard) seconds. This division gives a total of 88,750 seconds per ephemeris sol, just 25.2 seconds less than the average physical sol.

Robert Forward does not say how he would remedy his daily surplus of 23 seconds, but in my system, the additional seconds could be divided between each of the 25 hours, making each 50 minutes and 1.08 seconds long. For almost all practical purposes the extra second could be disregarded and clocks run a negligible 0.028 per cent slower. This adjustment would be indiscernible in the normal use of clocks and watches; timings required to be accurate to fractions of a second would be make using precisely calibrated timers. With this system of timing, a Martian hour would be only 50 seconds shorter than a Terran hour. Also, colonists would have something for which many of us have often wished – an extra hour in the day!

However, as Mr Gangale observed in "Martian Standard Time" (***JBIS***, Vol.39, p.283), it does seem doubtful that Martians would want a special time system when the existing terrestrial system could be easily, and virtually imperceptibly, adapted to suit the situation on Mars . Scientists and those having interests beyond Mars would need to use Universal Time anyway. I do not believe that the requirements of science need dictate that Mars must have a totally novel method of dividing the day; simply slowing the clock by 2.7 per cent, as proposed by Gangale and other, should meet all the colonist's chronometric needs, other than a few specialist requirements.

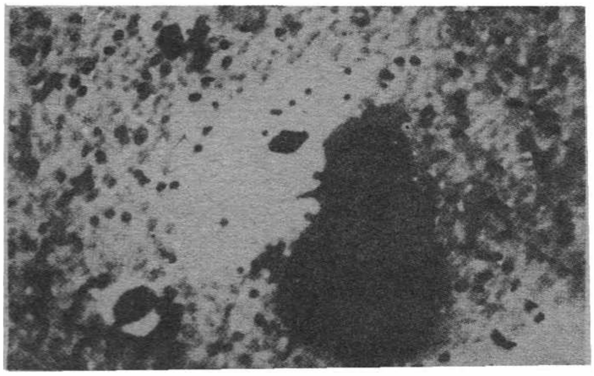
DAVID CHILDS
Aylesbury, Buckinghamshire, UK

"Martian Face"

Sir, I would like to suggest that the most interesting place on Mars for astronauts or cosmonauts to land at is in Cydonia, in the Martian northern hemisphere, to see if the famous "Martian Face", which is one mile wide and one-and-a-half-miles-long, is only a trick of light, or if it was chiseled by Martian winds, or by Martian hands.

This "Martian Face" in Cydonia, was first photographed in 1976 by the Viking satellite orbiting Mars.

ARTHUR J. STURTS
Warrington, Pennsylvania, U.S.A



The 'Martian Face' in Cydonia.

Dr. Gary Hunt Replies:

I note, with interest, the letter that has been submitted to you regarding this extraordinary face in the Cydonia region of Mars. I do not believe this is a direct indication of previous civilisations. The scale of this object is absolutely enormous and I believe it is just an extraordinary quirk of the photo illumination aspects due to erosion of what may probably turn out to be no more than a giant mesa system. It is extremely important to understand the surface geology of Mars and for this reason the whole surface will be mapped at a much higher resolution than we have had in the past. In this way we will then have a good idea of the geological processes that shape the surface as we now see it. For this reason Cydonia will be examined in greater detail rather than just for exploring this extraordinary face of Mars.

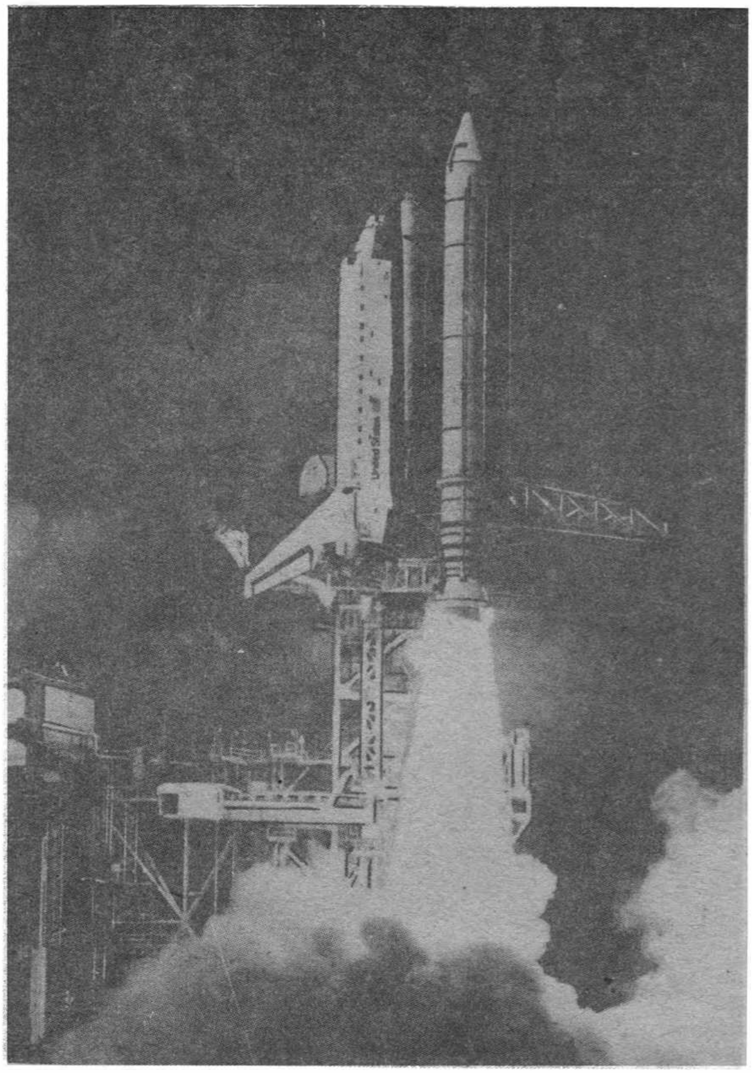
I think it would be wrong to put too much into this extraordinary picture that was seen by Viking. I can remember commenting on it as long ago as 1976 and I never expected it would still be in discussion now.

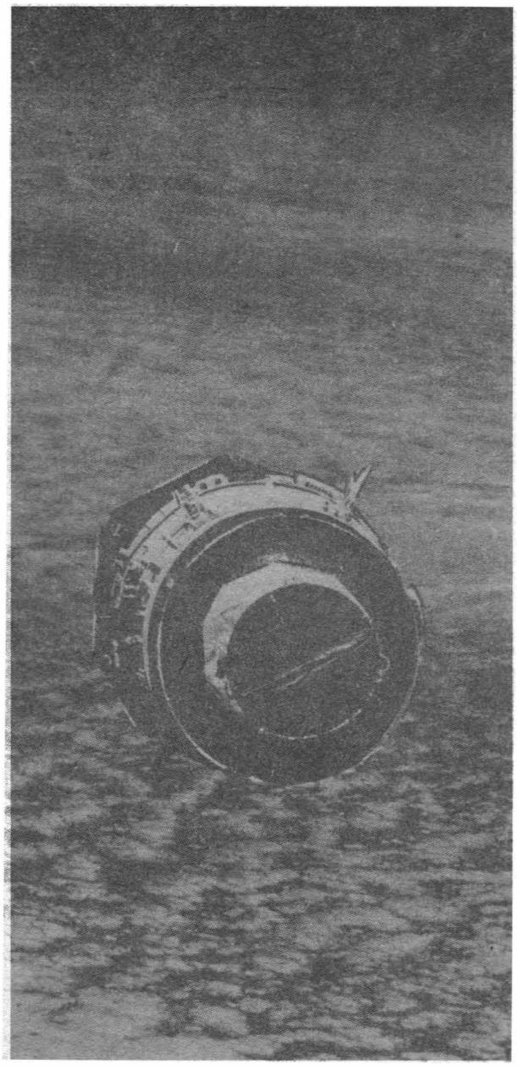
A Ring in Orbit

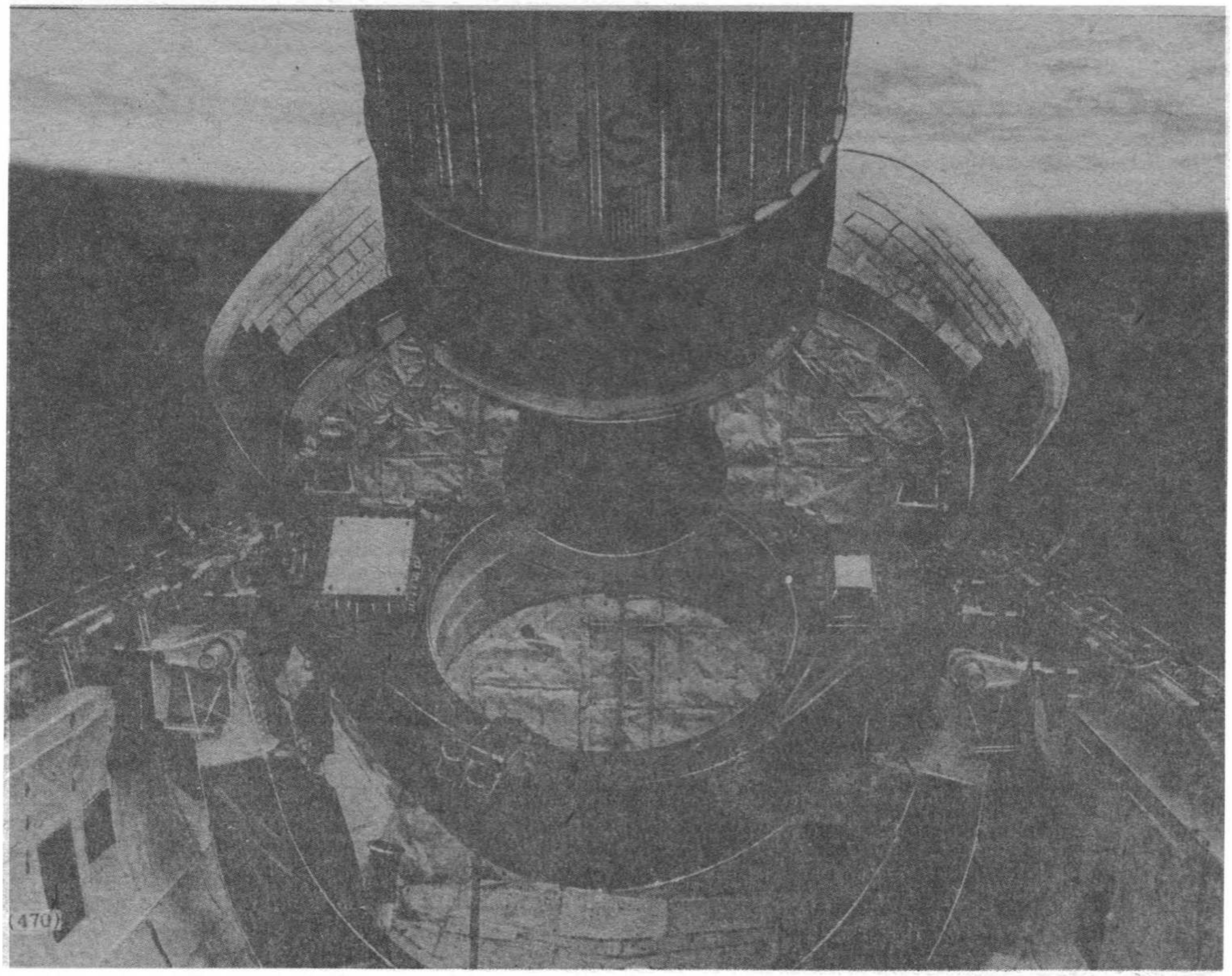
Sir, I understand that plans for Ariane to place a collapsible reflective ring into orbit to celebrate the centenary of the Eiffel Tower have been cancelled at the request of astronomers, much of whose photography is already hampered by the trails of artificial satellites. Although I appreciate this grievance, I still feel that such a ring (it would appear slightly larger than the full Moon in the sky) would work wonders for public awareness of spaceflight and particularly capture the interest of the younger generation.

Clearly the ring need not be permanent, it would quickly lose its appeal if it was, not to mention adding to the hazard of space debris. A rapidly decaying orbit would enhance the uniqueness of the spectacle and could serve to mollify the astronomers.

JONATHAN S.P. WORDIE
University of Reading, UK







MISSION REPORT STS-26

SHUTTLE

The Return to Flight

***Spaceflight* completes its definitive coverage of mission STS-26 with an article compiled from reports by *Roelof Shuiling* at the Kennedy Space Center and *Curtis Peebles* at Edwards Air Force Base.**

Discovery's ascent was almost a textbook performance. The shuttle flew a direct insertion profile, the main engines lifting Discovery straight into orbit and eliminating the need for an Orbital Manoeuvring System (OMS) burn to boost to orbit. At Main Engine Cut Off Discovery was within two feet per second of the planned velocity. An OMS burn made to circularise the orbit 42 minutes after launch left the orbiter in a 160 mile orbit.

"It's nice to be back in orbit," Commander Hauck said as Discovery began its first revolution of the globe.

Flight Day 1: Thursday, September 29

After their arrival in orbit the crew noted two problems. The left manoeuvring engine was experiencing a failure in the secondary thrust vector control power system. This minor problem was not of concern. The second was that condensation in the flash evaporator had turned to ice, partially blocking the duct. The flash evaporator is a cooling unit that operates during launch and reentry, supplementing the orbiter's radiators in the payload bay doors. This second problem resulted in the cabin temperature reaching over 80 degrees F. The crew were advised to wear shorts and to drink extra fluids. Mission Control pointed out the crew all lived in Texas and would feel at home in the heat.

Discovery's payload bay doors were opened at the T+ 1 hr 25 min point, in preparation for the mission's main task, the deployment of the Tracking and Data Relay Satellite-C (TDRC-C). Mission Specialist Mike Lounge was responsable for the deployment of the huge communications satellite and its Inertial Upper Stage (IUS) booster. The satellite was mounted on an Upper Stage Airborne Support structure in the aft of the payload bay. The support structure was tilted until the TDRS/IUS combination reached the correct deployment angle of 58 degrees.

After final checks the go-ahead was given for deployment. At approximately 21:43 GMT the satellite and its upper stage were separated from the support structure, springs providing the initial momemtum.

Commander Hauck and his Pilot Dick Covey then moved Discovery to a safe distance from the TDRS/IUS. One hour after its deployment the IUS-7 ignited its first stage solid rocket motor for a burn of 145 seconds. After coasting for about five hours 15 minutes the first stage separated. 12 hours 29 minutes after launch the IUS second stage began its work and at the completion of its 103 second burn the satellite was in geostationary orbit. (For full details of the TDRS system see ***Spaceflight***, November 1988, p.442).

After the successful deployment of TDRS-C the crew began their programme of research. They activated the Automated Directional Solidification Furnace (ADSF), Aggregation of Red Blood Cells (ARC) and Physical Vapour Transport of Organic Solids (PVTOS), middeck experiments which would operate while they slept.

Flight Day 2: Friday, September 30

On their first morning in space the crew of Discovery were awakened by the recorded voice of comedian Robin Williams calling. "Gooood Morning Discovery !!!" and continuing with a song written for the occasion.

The crew ran into trouble when they deployed Discovery's Ku-band communications antenna, as a problem had developed with its control system. This antenna pivots outward from the orbiter's payload bay and extends beyond the edge of the bay in the operating position. The crew was successful in rotating the antenna back into the payload bay for stowage. Had this not been possible the payload bay would have been unable to close. Astronauts Nelson and Lounge would have had to perform an unscheduled EVA to manually stow the antenna. The result of the problem was reduced communications capability since Discovery could not make use of the TDRS-1 satellite. All STS-26 communications had to take place while Discovery passed over ground stations on Earth.

The crew continued their programme of experiments. The Isoelectric Focusing Experiment (IFE) and the Phase Partitioning Experiment (PPE) were activated. Attempts were made by the crew to photograph lightning discharges from storms.

During the crew sleep period the ADSF began its second round of four runs and the PVTOS was also operating.

Flight Day 3: Saturday, October 1

The wake up call came in the form of a musical spoof of the song "I Get Around" titled "I Orbit Around".

The cabin temperatures were stable and improving somewhat as the ice blocking the cooling duct slowly melted. The flight deck temperature was 84 and the middeck was 79 degrees F.

The crew had a busy day of experiments ahead of them. Earth Limb Radiance (ELRAD) photographs were made to study the horizon in blue and ultraviolet light. The results of this experiment should be helpful for designing the horizon sensors used in geostationary satellites. Shuttle Student involvement experiments and the photography of lightning were also conducted.

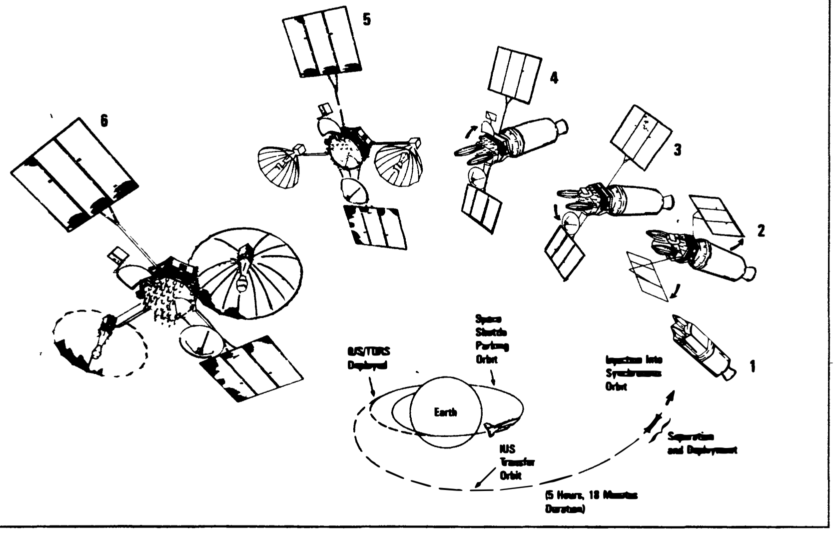
Rick Hauck practiced donning the bulky pressure suits which astronauts will now wear for launch and landing. Mission planners wanted to determine how long it took to put the suits on in weightless conditions so they could incorporate this in their timelines. The STS-26 crew were not keen on the pressure suit which they said made breathing and movement difficult during launch, they even hinted they would rather not wear them.

As the crew slept the ADSF and PVTOS

(Top left) Discovery blasts off from pad 39B at the Kennedy Space Center. (Bottom) The TDRS/IUS combination at the moment of release from the payload bay. (Top right) The TDRS/IUS drifts away from the orbiter. *NASA*

TDRS Deployment Sequence

1. Sequential release and deployment of TDRS appendages begin while the satellite is attached to the Inertial Upper Stage in the transfer orbit.
2. Outboard solar array panels are released and deployed. Solar panel operating configuration achieved.
3. Space/ground link antenna is released and deployed.
4. C-band antenna is released and latched. Then TDRS separates from the IUS.
5. Single access antennas (Ku- and S-bands) are released and are fully deployed.
6. Final operating configuration attained.



STS-26 MISSION REPORT

middeck experiments operated for their third cycles.

Flight Day 4: Sunday, October 2

The crew were awakened by students of Harvey Mudd College, where Pinky Nelson had once studied, singing their college song.

In preparation for the deorbit and landing the next day, the crew thoroughly checked out the Flight Control System. Middeck experiment activity continued with the completion of the Protein Crystal Growth Experiment. The crew also managed to photograph and videotape large scale storm activity.

Discovery's crew reported a problem with the air flow in the orbiter's troublesome air-driven waste management system (toilet). But after switching to a backup fan the crew reported no further difficulties.

During the afternoon the crew began to stow their equipment in preparation for landing.

Meanwhile over 30,000 km above them the TDRS-C performed a control system burn that began its drift towards its operational position of 171 degrees West.

The Discovery crew members held a press conference with reporters at Mission Control. They took this opportunity to pay tribute to their collegues who lost their lives onboard Challenger. Rick Hauck began:

"Today, up here where the blue sky turns to black, we can say at last, to Dick, Mike, Judy, to Ron and El, and to Christa and Greg: Dear friends we have resumed the journey that we promised to continue for you. Dear friends, your loss has meant we could confidently begin anew. Dear friends, your spirit and your dreams are still alive in our hearts." Then in turn each of Hauck's crew spoke in rememberance of the seven crew members of STS 51-L.

Prior to their last sleep period in orbit the crew activated the ADSF and PVTOS for the experiments' final runs.

Flight Day 5: Monday, October 3

Day 5 was devoted to the deorbit and landing. People had began arriving at Edwards Air Force Base (EAFB) hours in advance of Discovery's landing, at midnight over 300,000 people were at the base.

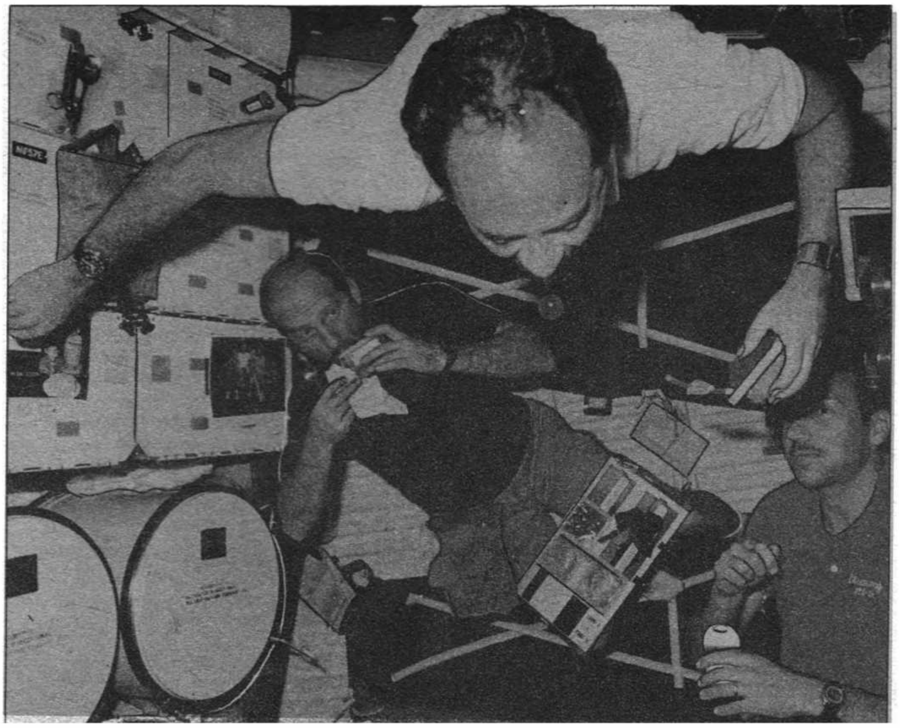
As the Sun rose the crowd began to drift towards the fence. Soon people were five and more rows deep in a line stretching several kilometres.

Meanwhile, orbiting high above, the astronauts woke to a hearty breakfast which included scrambled eggs, diced peaches, beef patty, bran flakes and fruit juice. The cabin temperature had fallen to 74.5 degrees F.

The crew then began final preparations for their return to Earth. The last of the middeck experiments were deactivated and stowed away. The crew donned their partial pressure suits and checked that the telescoping escape pole was in position and ready for use.

At about 7:39 (PDT) the Grumman Gulfstream Shuttle Training Aircraft began to make passes on the various landing approaches. The crowd had built upto some 410,000 people.

At 8:54 Commander Hauck began Discovery's deorbit OMS burn. At 9:09 C-band tracking data was received at Kwajalein soon after, the 14 minute communications black-out began as Discovery was enveloped in its firey reentry.



Lounge chases a bubble of strawberry drink which he had released with a plastic straw during mealtime on the middeck. In the background are Hauck (left) and Hilmers *NASA*

At 9:23 the black-out finished and Discovery resumed contact as it approached the Californian coast at hypersonic speed.

From the blue sky at Edwards Air Force Base came two sharp, powerful sonic booms. Cheers and applause went up from the crowd to greet Discovery's arrival. Far above two contrails appeared streaming from the orbiter's wings prompting more cheers.

As Discovery descended the contrails disappeared, the orbiter turned, banking steeply on its final approach, and lined up on Runway 17. Its flight, approximately North/South, paralleled the fence. It was as if the shuttle was making a parade pass for the hundreds of thousands, some of whom had been waiting for this moment for over a day.

At the runway's 2,500 ft mark Discovery's main landing gear touched down at 9:37:08 and the nose wheel ten seconds later. The orbiter decelerated as Rick Hauck applied the brakes and put the split rudder speed brake into operation. 39 seconds after touchdown Discovery came to a halt with a rollout distance of 7,451 ft.

As the crew onboard Discovery began their operations to safe the orbiter, ground support vehicles began to arrive. Access vehicles were positioned around the rear of the orbiter so that a line from the ground purge and cooling vehicles could be connected to the umbilical panels at the aft end of Discovery.

Once the ground crew was sure that any toxic gases had dispersed the mobile white room was brought to the crew hatch. At 10:32 the crew left the orbiter and were greeted by Vice-President George Bush, NASA Administrator James Fletcher, and Associate Administrator Richard Truly.

A post-landing inspection revealed damage to six tiles on Discovery's right hand wing. The tops of the tiles had been torn off by a collision of some kind. First reports stated that the diamond shaped abrasion was due to a collision with orbital debris or a bird strike. NASA now believes a piece of cork insulation broke away from a Solid Rocket Booster during launch and struck the orbiter's wing. The tiles will be replaced before Discovery's next flight.

The United States had returned to space with a highly successful mission. NASA Administrator James Fletcher indicated he had never seen as flawless a flight; including those of the Apollo programme.

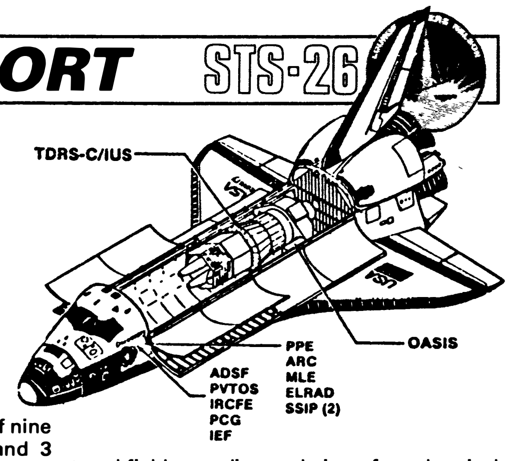
STS-26 at a Glance

LAUNCHED: September 29, 1988, 15:37 00 GMT
LAUNCH SITE: Pad 39B, Kennedy Space Center, USA
LANDED: October 3, 1988, 16.37:08 GMT
LANDING SITE: Runway 17, Edwards Air Force Base, USA
LIFT-OFF WEIGHT: 4,521,762 pounds
LANDING WEIGHT: 194,800 pounds
APOGEE: 176 nautical miles
PERIGEE: 163 nautical miles
INCLINATION: 28 45 degrees
DURATION: 97hrs 0min 57sec
ORBITS: 64

COMMANDER Frederick (Rick) Hauck
PILOT: Richard Covey
MISSION SPECIALIST 1: David Hilmers
MISSION SPECIALIST 2. John (Mike) Lounge
MISSION SPECIALIST 3: George (Pinky) Nelson

PRIMARY PAYLOAD: TDRS-C/IUS-7
SECONDARY PAYLOADS:
Orbital Experiments Autonomous Supporting Instrument System
Automatic Directional Solidification Furnace-2
Physical Vapour Transport of Organic Solids-2
Infrared Communications Flight Experiment
Protein Crystal Growth-II-I-1
Isoelectric Focussing Experiment
Handheld Microgravity Experiment
Aggregation of Red Blood Cells
Meoscale Lightning Experiment-1
Earth Limb Radiance Equipment
Student Experiments 82-04 and 82-05

STS-26 Experiments



Discovery carried many important experiments into orbit during its four day flight. Here we take a brief look at each experiment.

Infrared Communications Flight Experiment (IRCFE)
A new communications system for shuttle crews was tested in space for the first time during STS-26, instead of radio signals the system uses infrared light.

The Infrared Communications Flight Experiment (ICFE) may eventually form the basis of a new onboard crew communications system for the Space Shuttle and the Freedom space station.

The system is the brain child of Joseph Prather, at the Johnson Space Center (JSC), he says. "I think it's clearer than RF (radio frequency units. There is less interference. The world is very noisy RF-wise: A refrigerator can even generate RF interference. And there are so many RF users that the frequency you can use is very limited; the bandwidth is all used up."

Prather's is the most advanced two-way infrared system in the world, and he has been developing it since he joined the JSC in 1981 while still a student at the University of Washington in Seattle. He began working full-time at JSC in 1985. When his work began no two-way infrared system existed.

An experimental system designed by Prather was to have flown during 1986, the hault in shuttle flights gave Prather the chance to include improvements in the system.

Mission Specialist Pinky Nelson operated the system onboard Discovery, he plugged his standard lightweight headset into a belt-mounted unit. The belt is dotted with three infrared light emmiting diodes, which broadcast signals, and three photo diode modules which receive signals. Mounted in Discovery were three pairs of transmitter/receivers, one pair on the aft middeck wall and two pairs on the flight deck walls. Nelson tested the system by talking to the other crew members using the ICFE.

Infrared has many advantages over radio. The unit uses less power and can be made smaller, thus less instrusive on crew members, infrared also interfers less with many experiments.

Work is already underway to develop a 24-channel infrared communication system for Freedom space station.

Physical Vapour Transport of Organic Solids (PVTOS)
This experiment by the 3M Company is to produce organic thin films with ordered crystalline structures and to study their optical, electrical and chemical properties.

The name of the experiment Physical Vapour Transport of Organic Solids (PVTOS) is derived from the method which is employed to produce organic crystals – vapour transport.

The PVTOS experiment consists of nine independent cells 12 inches long and 3 inches in diameter. Each cell contains a test tube-like ampule containing organic material. During space flight the organic material is vapourised. Migrating through a buffer gas the vapourised material forms a highly ordered thin film on a flat surface.

Protein Crystal Growth (PCG) Experiment
This experiment explored the potential advantages of using protein crystals grown in space to determine the complex, three-dimensional structure of specific protein molecules.

Knowing the precise structure of the complex molecules provides the key to understanding their biological function and could lead to method of altering or controlling the function in a way that might result in new drugs.

Protein crystal growth experiments flown on four previous Space Shuttle missions have shown promising evidence that superior crystals can be grown in the microgravity environment of space flight.

One experiment is with transcriptase. The enzyme is a chemical key to the replication of the AIDS virus. More detailed knowledge of its three-dimensional structure could lead to new drug treatments for AIDS.

Automated Directional Solidification Furnace (ADSF)
The ADSF is a special space furnace being developed and managed by the Marshall Space Flight Center. It is designed to demonstrate the possibility of producing stronger lighter and better-performing magnetic composite materials in a microgravity environment.

Four furnaces are included on the ADSF, each processing a single sample. The samples used on the STS-26 mission are manganese and bismuth composites.

All the ADSF hardware is reuseable. The experiment most recently flew aboard STS 51-G.

Aggregation of Red Blood Cells (ARC)
Blood samples from donors with such medical conditions as heart disease, hypertension, diabetes and cancer flew in this experiment.

The experiment was designed to provide information on the formation rate, structure and organisation rate of red cell clumps, as well as on the thickness of the whole blood cell aggregrates at high low flow rates. The experiment will help determine if microgravity can play a beneficial role in new and existing clinical research and medical diagnostic tests.

The experiment flew once before on STS 51-C in January 1985.

Isoelectric Focusing (IEF)
IEF is a type of electrophoresis experiment which separates proteins in an electrical field according to their surface electrical charge.

The isoelectric focusing technique applies an electric field to a column of conducting liquid containing certain molecules which create a pH gradient in the column (alkalinity at one end, acidity at the other end). This pH gradient causes the biological sample to move to a location in the column where it has zero charge – its ioselectric point.

Meoscale Lightning Experiment (MLE)
MLE is an experiment designed to obtain night time images of lightning in an attempt to better understand the effects of lightning discharges on each other, on nearby storms and on storm microbursts and wind patterns and to determine interrelationships over an extremely large geographical area.

The experiment uses payload bay cameras to observe lightning discharges at night from active storms. The experiment uses colour video cameras and a 35mm hand-held film camera to provide coverage of an area roughly 200 by 150 miles directly below the shuttle.

Phase Partioning Experiment (PPE)
The PPE is designed to fine tune understanding of the role of gravity and other physical forces play in separating, i.e. partioning biological substances between two unmixable liquid phases.

Photos of the separation were recorded with a 35mm Nikon camera equipped with an hour/minute/second time-tag.

Earth-Limb Radiance Experiment (ELRAD)
The aim of the ELRAD experiment was to photograph the Earth's 'horizon twilight glow' near sunrise and sunset. The ELRAD camera was mounted in one of the orbiter's windows pointing towards the horizon, a photograph was taken every 10 seconds.

The photographs will allow scientists to measure the radiance of the twilight sky as a measure of the Sun's position below the horizon. This information should allow designers to develop better more accurate horizon sensors for geosynchronous communications satellite.

Shuttle Student Involvement Project Utilising a Semi-Permeable Membrane to Direct Crystal Growth
The experiment was to control crystal growth through the use of a semi-permeable membrane.

Effects of Weightlessnss on Grain Formation and strength in Metals
The experiment was to heat a titanium alloy metal filament to near the melting point to observe the effect that weightlessnesss has on crystal reorganisation within the metal.

STS-26 MISSION REPORT

COMMANDER
Frederick (Rick) Hauck (Captain, USN)

BIRTHPLACE AND DATE: Born April 11, 1941, in Long Beach, California, but considers Winchester, Massachusetts, and Washington, D.C., to be his hometowns. His mother, Mrs. Virginia Hauck, resides in Winchester, Massachusetts. His father was the late Captain Philip F. Hauck, USN.

PHYSICAL DESCRIPTION: Blond hair; blue eyes; height: 5 feet 9 inches; weight: 175 pounds.

EDUCATION: Graduated from St. Albans School in Washington, D.C. in 1958; received a bachelor of science degree in Physics from Tufts University in 1962 and a master of science degree in Nuclear Engineering from the Massachusetts Institute of Technology in 1966.

MARITAL STATUS: Married to the former Dolly Bowman of Washington, D.C.

CHILDREN: Ms. Whitney Hauck Wood; Stephen Christopher Hauck.

RECREATIONAL INTERESTS: During his spare time, he enjoys skiing, sailing, squash, and working on his 1958 Corvette.

ORGANISATIONS: Associate Fellow, the American Institute of Aeronautics and Astronatics, and the Society of Experimental Test pilots

SPECIAL HONOURS: The Defense Distinguished Service Medal, the Distinguished Flying Cross; the Air Medal (9); the Navy Commendation Medal with Gold Star and Combat V; the NASA Medal for Outstanding Leadership; the NASA Space Flight Medal (2); the Presidential Cost Saving Commendation; Lloyd's of London Silver Medal for Meritorious Service; the American Astronautical Society Flight Achievement Award; the Federation Aeronautique Internationale (FAI) Yuri Gagarin Gold Medal; the FAI Komarov Diploma (2); the Tufts University Presidential Medal; and the Delta Upsilon Distinguished Alumnus Award. He was named the Navy's Outstanding Test Pilot for 1972.

EXPERIENCE: Hauck, a Navy ROTC student at Tufts University, was commissioned upon graduation in 1962 and reported to the USS WARRINGTON (DD-843) where he served 20 months as communications officer and CIC officer. In 1964, he attended the U.S. Naval Postgraduate School, Monterey, California, for studies in maths and physics and, for a brief time in 1965, studied Russian at the Defense Language Institute in Monterey. Selected for the Navy's Advanced Science Program, he received his master's degree in Nuclear Engineering from MIT the next year.

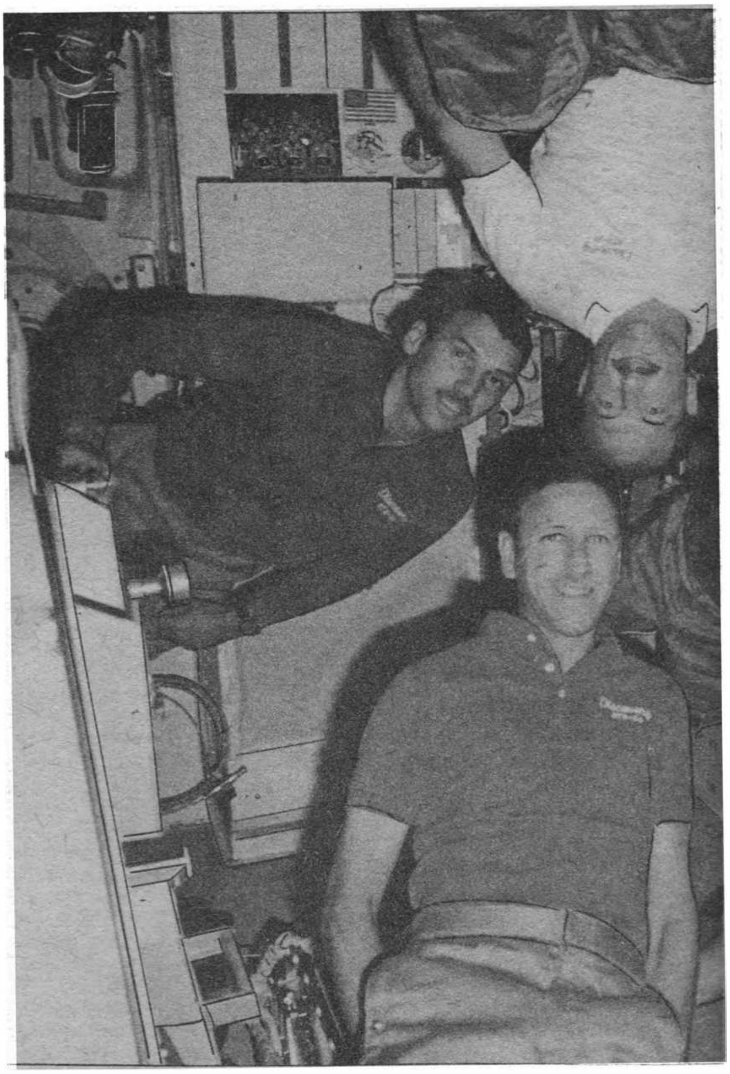
He commenced flight training at the Naval Air Station, Pensacola, Florida, in 1966, and upon receiving his wings in 1968, he reported to the Naval Air Station at Oceana, Virginia, for replacement pilot training in the A-6. Hauck then reported to VA-35 where he served successfully as line division officer and safety officer. During this tour he deployed to the Western Pacific with Air Wing 15 aboard USS CORAL SEA (CVA-43), flying 114 combat and combat support missions.

In August 1970 Hauck returned to the east coast A-6 replacement training squadron, VA-42, as a visual weapons delivery instructor. Selected for test pilot training, he reported to the U.S. Naval Test Pilot School at Patuxent River, Maryland, in 1971. A 3-year tour in the Naval Air Test Center's Carrier Suitability Branch of the Flight Test Division followed. During this tour, Hauck served as a project test pilot for automatic carrier landing systems in the A-6, A-7, F-4, and F-14 aircraft and was team leader for the Navy Board of Inspection and Survey aircraft trials of the F-14. In 1974, he reported as operations officer to Commander Carrier Air Wing 14 aboard USS ENTERPRISE (CV(N)-65). During this tour, he flew the A-6, A-7, and F-14 during both day and night carrier operations. He reported to Attack Squadron 145 as executive officer in February 1977, following a brief tour in VA-128.

Hauck has logged almost 5,000 hours flying time.

NASA EXPERIENCE: Hauck was selected as an astronaut candidate by NASA in January 1978. In August 1979 he completed a 1-year training and evaluation period qualifying him for assignment as a pilot on future Space Shuttle flight crews. He was a member of the support crew for STS-1, the first Shuttle Orbiter mission, and was the reentry capsule communicator (CAPCOM) on the support crew for STS-2. Subsequently he was a project test pilot for development of flight techniques and landing aids in preparation for the first orbiter night landing.

Hauck was pilot for STS-7, which launched from Kennedy Space Center, Florida, on June 18, 1983. The crew included Bob Crippen (spacecraft commander), and three mission specialists, John Fabian, Sally Ride, and Norm Thagard. This was the second flight for the Orbiter Challenger and the first mission with a 5-person crew. During the mission, the STS-7 crew deployed satellites for Canada (ANIK C-2) and Indonesia (PALAPA B-1); operated the Canadian-built Remote Manipulator System (RMS) to perform the first deployment and retrieval exercise with the Shuttle Pallet Satellite (SPAS-01); conducted the first information flying of the orbitor with a free-flying satellite (SPAS-01); carried and operated the first U.S./German cooperative materials science payload (OSTA-2); operated the Continuous Flow Electrophoresis System (CFES) and the Monodisperse Latex Reactor (MLR) experiments, and activated seven Getaway Specials. Mission duration was 147 hours before landing on a lakebed runway at Edwards Air Force Base, California, on June 24, 1983.



The STS-26 crew pose for a photograph in Discovery's middeck (Clockwise from the top)

Hauck was next spacecraft commander of STS 51-A which launched from Kennedy Space Center, Florida, on November 8, 1984. His crew included Dave Walker (pilot), and three mission specialists, Joe Allen, Anna Fisher, and Dale Gardner. This was the second flight of the orbiter Discovery. During the mission the crew deployed two satellites, Telesat Canada's Anik D-2, and Hughes' LEASAT-1 (Syncom IV-1), and operated the 3M Company's Diffusive Mixing of Organic Solutions (DMOS) experiment. In the first space salvage mission in history the crew also retrieved for return to Earth the Palapa B-2 and Westar VI satellites. STS 51-A completed 127 orbits of the Earth before landing at Kennedy Space Center, Florida, on November 16, 1984.

In March 1985 Captain Hauck became the Astronaut Office Project Officer for the integration of the liquid fuelled Centaur upper stage into the Space Transportation System. In May 1985 he was named Commander of the European Space Agency sponsored Ulysses mission. The Shuttle Centaur project was terminated in July 1986. In August 1986 Captain Hauck was appointed NASA Associate Administrator for External Relations, Washington D.C. He resumed his astronaut duties at the Johnson Space Center in early February 1987.

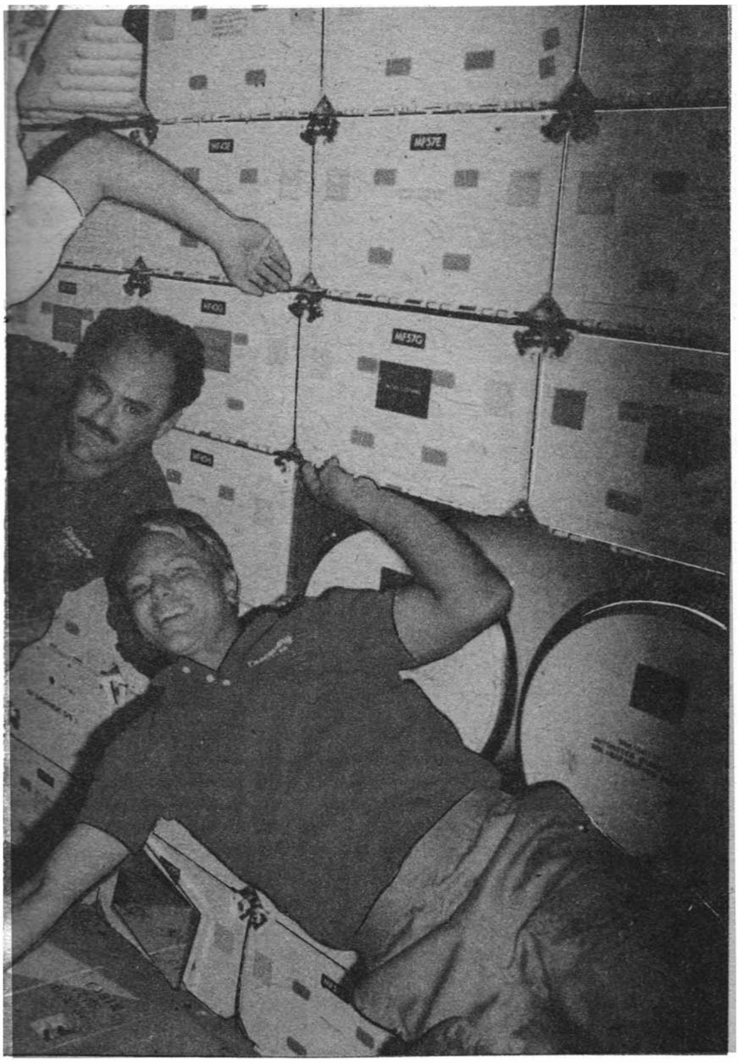
SPACE EXPERIENCE: 435 hr 9 min 52 seconds.

PILOT
Richard O. Covey (Colonel, USAF)

BIRTHPLACE AND DATE: Born August 1, 1946, in Fayetteville, Arkansas, but considers Fort Walton Beach, Florida, to be his hometown. His mother, Mrs. Patricia O. Covey, resides in Fort Walton Beach, Florida. His father, Lt. Col. Charles D. Covey, USAF (Ret.), is deceased.

PHYSICAL DESCRIPTION: Brown hair; grey eyes; height: 5 feet 11-½ inches; weight: 150 pounds.

EDUCATION: Graduated from Choctawhatchee High School, Shalimar, Florida, in 1964; received a bachelor of science degree in Engineering Sci-



ick Hauck, Mike Lounge, Pinky Nelson, Dick Covey, and Dave Hilmers. *NASA*

ences from the United States Air Force Academy in 1968 and a master of science degree in Aeronautics and Astronautics from Purdue University in 1969

MARITAL STATUS: Married to the former Kathleen Allbaugh of Emmettsburg, Iowa. Her parents, Mr. and Mrs. Eugene B. Allbaugh, are residents of Saratoga, California.

CHILDREN: Sarah Suzanne, February 5, 1974; Amy Kathleen, May 18, 1976.

RECREATIONAL INTERESTS: He enjoys golf, water sports, photography, skiing, and youth sports coaching.

ORGANISATIONS: Member of the Air Force Association, the Order of Daedalians, and the USAF Academy Association of Graduates; associate member of the Society of Experimental Test pilots.

SPECIAL HONOURS: Awarded the Department of Defense Superior Service Medal, 4 Air Force Distinguished Flying Crosses, 16 Air Medals, the Air Force Meritorious Service Medal, the Air Force Commendation Medal, the NASA Space Flight Medal, and the Johnson Space Center Certificate of Commendation. He is a Distinguished Graduate of the U.S. Air Force Academy, and received the Liethen-Tittle Award as the Outstanding Graduate of USAF Test Pilot School Class 74B.

EXPERIENCE: Between 1970 and 1974, Covey was an operational fighter pilot, flying the F-100, A-37, and A-7D. He flew 339 combat missions during two tours in Southeast Asia. At Eglin Air Force Base, Florida, between 1975 and 1978, he was an F-4 and A-7D weapons system test pilot and Joint Test Force Director for electronic warfare testing of the F-15 "Eagle". He has flown over 4,000 hours in more than 25 different types of aircraft.

NASA EXPERIENCE: Selected as an astronaut candidate by NASA in January 1978, Covey completed a 1-year training and evaluation period and became an Astronaut in August 1979.

Prior to the first flight of the Space Shuttle, he provided astronaut support in Orbiter engineering development and testing. He was a T-38 chase pilot for the second and third Shuttle flights and support crewman for the first operational Shuttle flight, STS-5. Additionally, Covey served as Mission Control spacecraft communicator (CAPCOM) for Shuttle missions STS-5, 6, 61-B, 61-C, and 51-L.

Covey was pilot of STS 51-I which was launched from Kennedy Space Center, Florida, on August 27, 1985. Crew members included Joe Engle (spacecraft commander), and three mission specialists Mike Lounge, Bill Fisher, and Ox van Hoften. The mission was acknowledged as the most successful Space Shuttle mission yet flown. The crew deployed three communications satellite, the Navy SYNCOM IV-4, the Australian AUSSAT, and American Satellite Company's ASC-1. The crew also performed the the sucessful on-orbit rendezvous and repair of the ailing 15,000 lb SYNCOM IV-3 satellite. This repair activity involved the first manual grapple and manual deployment of a satellite by a crew member. STS 51-I completed 112 orbits of the Earth before landing at Edwards Air Force Base, California, on September 3, 1985. With the completion of this flight Covey has logged over 170 hours in space.

SPACE EXPERIENCE: 267 hr 18 min 39 seconds.

MISSION SPECIALIST 1
David C. Hilmers (Lieutenant Colonel, USMC)

BIRTHPLACE AND DATE: Born January 28, 1950, in Clinton, Iowa, but considers DeWitt, Iowa, to be his hometown. His father, Paul C. Hilmers, lives in Clinton, Iowa, and his mother, Matilda Hilmers, lives in DeWitt, Iowa.

PHYSICAL DESCRIPTION: Brown Hair; Brown eyes; height: 5 feet 11-½ inches; weight: 165 pounds.

EDUCATION: Graduated from Central Community High School in DeWitt, Iowa, in 1968; received a bachelor of arts degree in Mathematics (Summa Cum Laude) from Cornell College in 1972; a master of science degree in Electrical Engineering (with distinction) in 1977, and the degree of Electrical Engineer from the U.S. Naval Postgraduate School in 1978.

MARITAL STATUS: Married to the former Lynn Beneke of Vinton, Iowa. Her parents, Mr. and Mrs. Leland Beneke, reside in Vinton, Iowa.

CHILDREN: Matthew D., September 28, 1976; and Daniel J., August 10, 1979.

RECREATIONAL INTERESTS: He enjoys playing the piano, gardening, electronics, spending time with his family, and all types of sports.

ORGANISATIONS: Phi Beta Kappa, and Eta Kappa Nu.

SPECIAL HONOURS: Named Outstanding Scholar-Athlete, Midwest Conference (1971); graduated Summa Cum Laude from Cornell College (1972); awarded an NCAA Post-Graduate Fellowshp (1972); named to Phi Bete Kappa and named Outstanding Athlete, Cornell College (1972).

EXPERIENCE: Hilmers entered on active duty with the United States Marine Corps in July 1972. After completing Marine Corps Basic School and Flight School, he was assigned to VMA(AW)-121 at Marine Corps Air Station Cherry Point, North Carolina, flying the A-6 Intruder. In 1975, he became an air liaison officer with the 1st Battalion, 2d Marines, stationed with the 6th Fleet in the Mediterranean. He graduated from the U.S. Naval Postgraduate School in 1978 and was later assigned to the 1st Marine Aircraft Wing in Iwakuni, Japan. He was stationed with the 3d Marine Aircraft Wing in El Toro, California, at the time of his selection by NASA.

NASA EXPERIENCE: Hilmers was selected a NASA astronaut in July 1980 and completed the initial training period in August 1981. In 1983 he was selected as a member of the "launch ready standby crew". His early NASA assignments have included work on upper stages such as PAM, IUS, and Centaur, as well as Shuttle software verification at the Shuttle Avionics Integration Laboratory (SAIL). In addition, he was the Astronaut Office training coordinator, worked on various Department of Defense payloads, and also served as a capsule communicator (CAPCOM) at Mission Control for STS 41-D, 41-G, 51-A, 51-C, and 51-D.

In February 1985 he was named to STS 51-J, a classified Department of Defense mission, which launched from Kennedy Space Center, Florida, on October 3, 1985. This was the maiden voyage of the Atlantis, the final Orbiter in the Shuttle fleet. As a mission specialist on this flight, he had prime responsibility for a number of on-orbit activities during the mission. After 98 hours of orbital operations, Atlantis landed at Edwards Air Force Base, California, on October 7, 1985.

In May 1985 he was named to the crew of STS 61-F which was to deploy the Ulysses spacecraft on an interplanetary trajectory using a Centaur upper stage. This mission was to have flown in May 1986, but the Shuttle Centaur project was terminated in July 1986, and Hilmers then worked in the areas of payload safety and shuttle on-board software. During 1987 he was involved in training for STS-26 and in flight software development.

SPACE EXPERIENCE: 194 hr 46 min 27 seconds.

MISSION SPECIALIST 2
John M. "Mike" Lounge

BIRTHPLACE AND DATE: Born June 28, 1946, in Denver, Colorado, but considers Burlington, Colorado, to be his hometown. His parents, Mr. and Mrs. Percy Lounge, reside in Burlington.

PHYSICAL DESCRIPTION: Brown hair; brown eyes; height: 5 feet 10 inches; weight: 165 pounds.

EDUCATION: Graduated from Burlington High School, Burlington, Colorado, in 1964; received a bachelor of science degree in Physics and Mathematics from the United States Naval Academy in 1969 and a master of science degree in Astrogeophysics from the University of Colorado in 1970.

MARITAL STATUS: Married to Kathryn Anne Havens of Port Arthur, Texas; she is a Payload Integration Manager for the National Space Transportation System Program at the Johnson Space Center.

CHILDREN: Shannon, June 5, 1971; Kenneth, September 14, 1981; Kathy, March 23, 1984.

RECREATIONAL INTERESTS: He enjoys jogging, chess, squash, tennis, flying, golfing and blue grass guitar.

ORGANISATIONS: Member of the Aircraft Owners and Pilots Association, the American Institute of Aeronautics and Astronautics, the Human Factors Society, and the Civil Air Patrol.

SPECIAL HONOURS: 6 Navy Air Medals, 3 Navy Commendation Medals (with Combat "V"), the JSC Superior Achievement Award (for service as a member of the Skylab Reentry Team), and NASA Space Flight Medal.

EXPERIENCE: Lounge entered on active duty with the United States Navy following graduation from the U.S. Naval Academy and spent the next nine years in a variety of assignments. He completed Naval flight officer training at Pensacola, Florida, went on to advanced training as a radar intercept officer in the F-4J Phantom, and subsequently reported to Fighter Squadron 142 based at Naval Air Station Miramar, California. While with VF-142, he completed a 9-month Southeast Asia cruise aboard the USS ENTERPRISE (participating in 99 combat missions) and a 7-month Mediterranean cruise aboard the USS AMERICA. In 1974, he returned to the U.S. Naval Academy as an instructor in the Physics Department. Lounge transfered to the Navy Space Project Office in Washington, D.C., in 1976, for a 2-year tour as a staff project officer. He resigned his regular United States Navy commission in 1978 and affiliated witht he Naval Air Reserve, flying F-4Ns with Reserve Fighter Squadron 201 at the Naval Air Station Dallas, Texas. He currently holds the rank of Lieutenant Colonel in the Texas Air National Guard, and is assigned to the 147th Fighter Interceptor Group at Ellington Air National Guard Base.

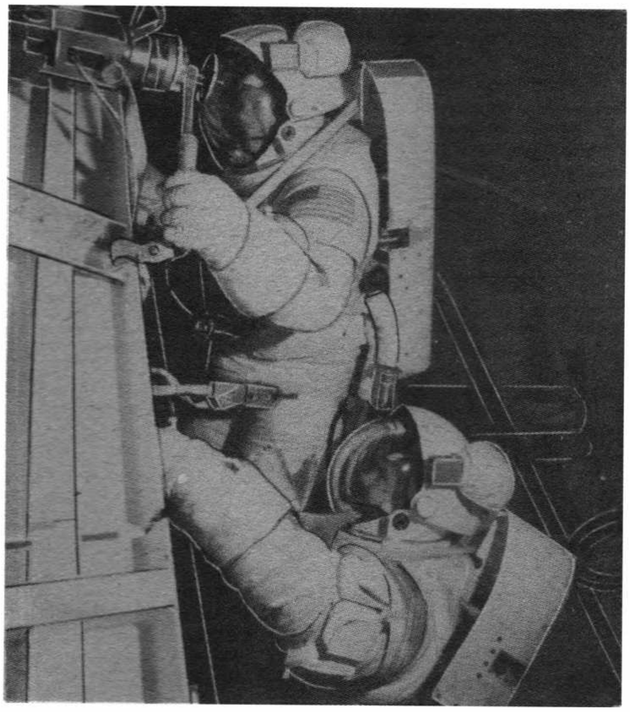
NASA EXPERIENCE: Mr. Lounge has been employed at the Lyndon B. Johnson Space Center since July 1978. During this time, he worked as lead engineer for the integration of spin stabilised booster stages for Space Shuttle launched satellites, and also served as a member of the Skylab Reentry Flight Control Team. He completed these assignments while with the Payloads Operations Division.

Selected as an astronaut candidate by NASA in 1980, he completed a 1-year training and evaluation period, and became an astronaut in August 1981. He served as a member of the launch support team at Kennedy Space Center for the STS-1, STS-3 missions. Mr. Lounge has also specialised in the Space Shuttle's computer system and has been involved in CRT display design for various applications.

Mr. Lounge served as a mission specialist on STS 51-I which launched from Kennedy Space Center, Florida, on August 27, 1985. The crew included Joe Engle (spacecraft commander), Dick Covey (pilot), and fellow mission specialists Bill Fisher & Ox van Hoften. The mission was acknowledged as the most successful Space Shuttle mission yet flown. During this mission his duties included deployment of the Australian AUSSAT communications satellite and operation of the Remote Manipulator System (RMS). The crew deployed two other communications satellites, the Navy's SYNCOM IV-4, and American Satellite Company's ASC-1, and also performed a successful on-orbit rendezvous and repair of the ailing 15,400 lb SYNCOM IV-3 satellite. STS 51-I completed 112 orbits of the Earth before landing at Edwards Air Force Base, California, on September 3, 1985.

Following his flight on STS 51-I, he was assigned to the first mission to carry the Centaur (cryogenically fuelled) upper stage (STS 61-F). After that mission was cancelled, he participated in Space Station design development.

SPACE EXPERIENCE: 267 hr 18 min 39 seconds



Nelson and Lounge practice a contigency EVA in the Weightless Environment Training Facility (WET-F) to manually upright the TDRS from its stowed position if the automatic system were to fail. Nelson is above with his hand on the wrench. *NASA*

MISSION SPECIALIST 3
George D. (nickname Pinky) Nelson

BIRTHPLACE AND DATE: Born July 13, 1950, in Charles City, Iowa Considers Willmar, Minnesota, to be his hometown. His parents, Mr. and Mrs. George V. Nelson, are residents of Clinton, Iowa.

PHYSICAL DESCRIPTION: Blond hair; blue eyes; height: 5 feet 9 inches; weight: 170 pounds.

EDUCATION: Graduated from Willmar Senior High School, Willmar, Minnesota, in 1968; received a bachelor of science degree in Physics from Harvey Mudd College in 1972 and a master of science and a doctorate in Astronomy from the University of Washington in 1974 and 1978, respectively.

MARITAL STATUS: Married to the former Susan Lynn Howard of Alhambra, California. Her mother, Mrs. Louise O. Howard, resides in Houston, Texas.

CHILDREN: Aimee Tess, April 25, 1972; Marti Ann, February 27, 1975.

RECREATIONAL INTERESTS: He enjoys playing golf, swimming, running, music, and reading.

EXPERIENCE: Nelson performed astronomical research at the Sacramento Peak Solar Observatory, Sunspot, New Mexico; the Astronomical Institute at Utrecht, Utrecht, the Netherlands; and the University of Gottingen Observatory, Gottingen, West Germany, and at the Joint Institute for Laboratory Astrophysics in Boulder, Colorado.

NASA EXPERIENCE: Dr. Nelson was selected as an astronaut candidate by NASA in January 1978.

Since coming to NASA he has performed various jobs in the Astronaut Office. He flew as a scientific equipment operator in the WB 57-F Earth resources aircraft; served as the Astronaut Office representative in the Space Shuttle Extravehicular Mobility Unit (space suit) development effort. During STS-1 he was the photographer in the prime chase plane. He also served as support crewman and CAPCOM for the last two OFT flights, STS-3 and STS-4, and as head of the Astronaut Office Mission Development Group.

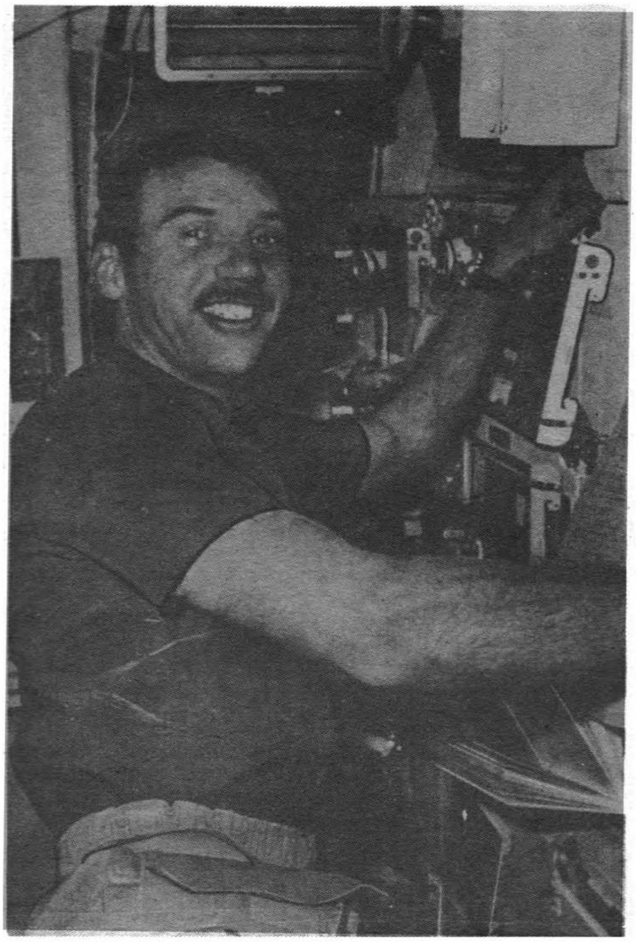
He flew on STS 41-C which launched from the Kennedy Space Center, Florida, on April 6, 1984. During this mission the crew successfully deployed the Long Duration Exposure Facility (LDEF); retrieved the ailing Solar Maximum Satellite, repaired it on-board the orbiting Challenger, and replaced it in orbit, using the robot arm called the Remote Manipulator System (RMS). The mission also included flight testing of Manned Manoeuvring Units (MMU's) in two extravehicular activities (EVA's); operation of the Cinema 360 and IMAX Camera Systems. Mission duration was 7-days before landing at Edwards Air Force Base, California, on April 13, 1984.

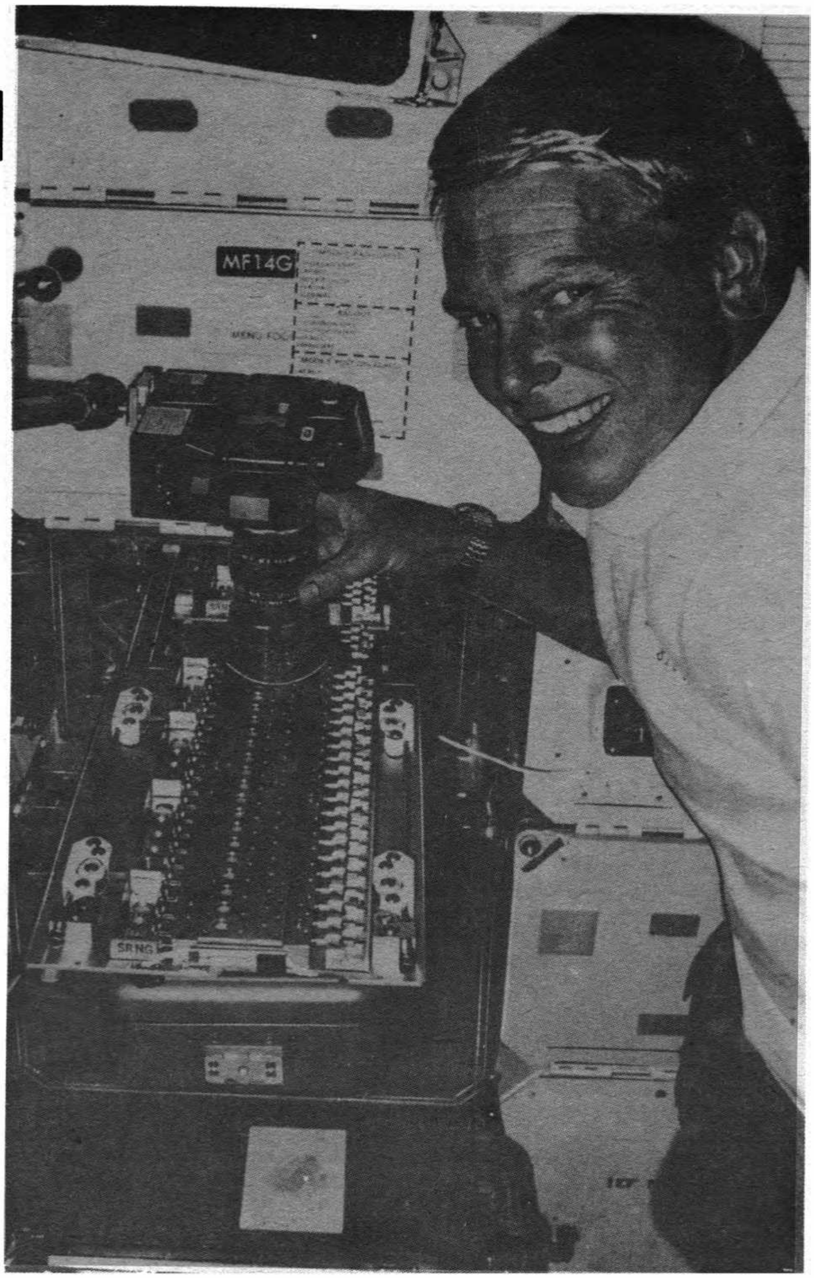
He next flew on STS 61-C which launched from the Kennedy Space Center, Florida, on January 12, 1986. During the 6-day flight of Columbia the crew deployed the SATCOM KU satellite, and conducted experiments in astrophysics and materials processing STS 61-C made a night landing at Edwards Air Force Base, California, on January 18, 1986. He has over 1o hours of EVA experience.

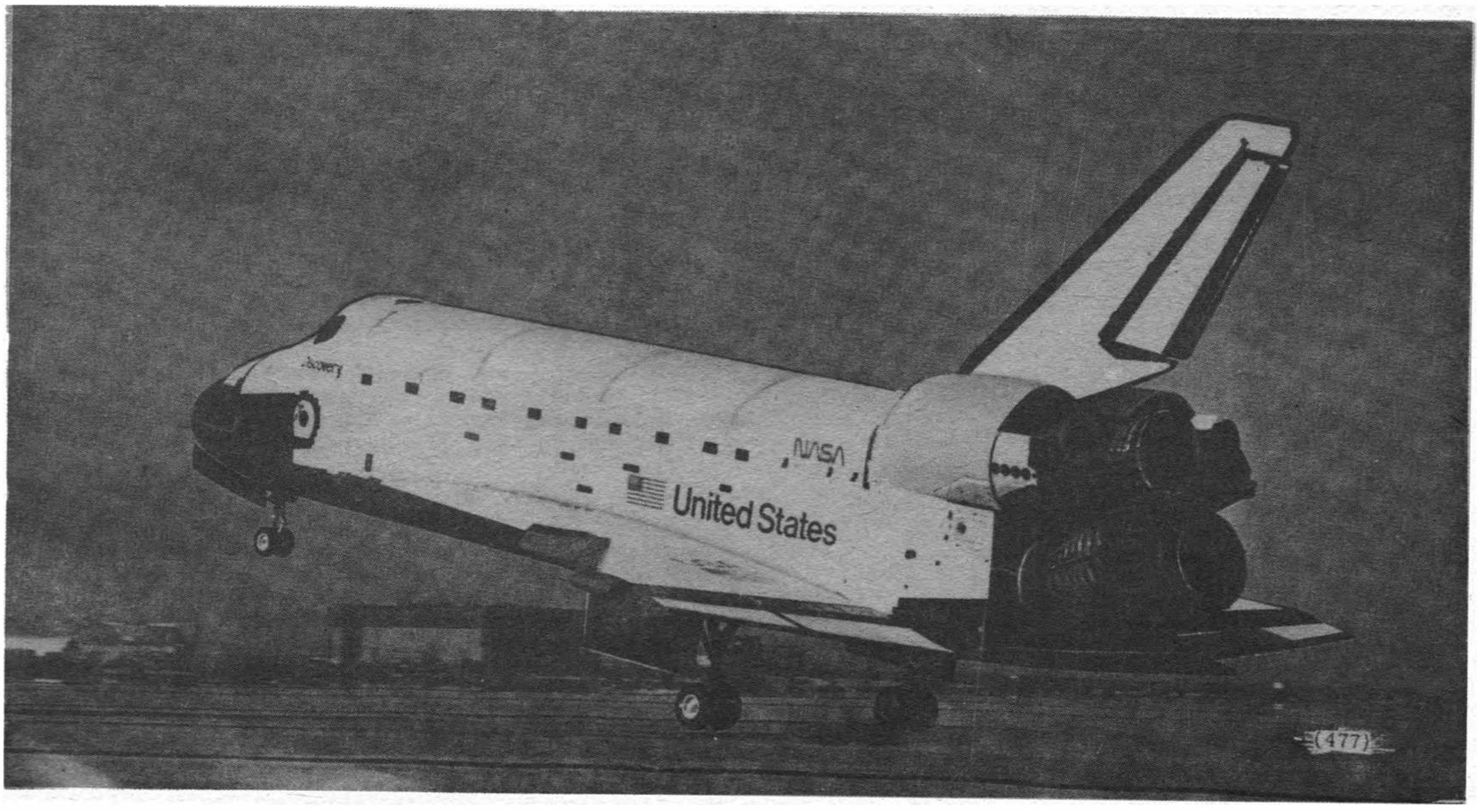
SPACE EXPERIENCE: 410 hr 45 min 11 seconds

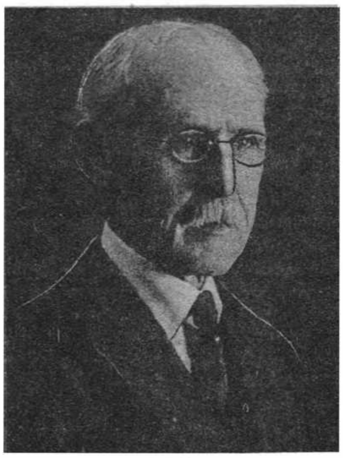
STS-26

(Top left) Mission Specialist Dave Hilmers on the middeck. (Top right) Pinky Nelson uses a 35mm camera to photograph one of the STS-26 protein crystal growth experiments. (Bottom) Discovery touches down at the completion of its four day flight on the dry lake bed at Edwards Air Force Base. *NASA*









Garrett P. Serviss (1851-1929).
Cornell University

Under the Stars with Garrett P. Serviss

There is an unsurpassed charm that comes from knowing the night sky. Perhaps the feeling comes from a recipe which blends astronomy, mythology, and a sense of concordance with the rhythm of the seasons. Writers on popular astronomy are faced with the delicate task of conveying scientific facts along with a sense of the beauty of the cosmos. None ever reponded better to this challenge than Garrett P. Serviss (1851-1929), who time and again expressed his vision: "The splendors of Aladdin's Cave are for children, and fade in the light of advancing life, but these glories of the universe are for men and women, and grow brighter with the years."

Serviss is primarily remembered for two achievements; he was a pioneer in spreading the gospel of astronomy to the public, and he was a master of the language.

Walter Scott Houston, writing in the August 1988 *Sky and Telescope*, precipitated this piece by remarking that 1988 marked the 100th anniversary of Serviss' *Astronomy with an Opera-Glass*, "the first American book targeted for people who wanted to become familiar with the night sky." In the 1940's, when I began to read books pointed toward the amateur astronomer, Serviss' works were still competitive but had been joined by the worthy William Tyler Olcott (1873-1936) and others. Even in the 1970's, a sweep through used bookstores in the Los Angeles area yielded a harvest of the familiar blue-covers-with-gold-letters of Serviss.

Uranography, the description of the heavens by maps or words, derives from Urania, the Greek muse of astronomy, and has a significant intersection with the simple practice of stargazing. Uranography and stargazing, stirred together in suitable proportions, will suffice to describe Serviss' chosen field. One might care to add a dash of astrophysics, but not too much.

This class of sky poets – remember, in the oldest traditions, poets conveyed knowledge as well as delight – are an under-appreciated set whose own song has yet to be sung. The Greek astronomical poet Aratos (fl. 3rd C. B.C.) is an early member of the honour roll. Serviss was preceded in modern times by the well-known Rev. T.W. Webb (1807-1885), whose *Celestial Objects for Common Telescopes* persists in a Dover Books edition. Another Englishman, Admiral W. H. Smyth (1788-1865), issued his *Cycle of Celestial Objects* in 1844. His descriptions of double stars are worth reading even on a cloudy night as are the historical researches of Richard Hinckley Allen in his 1899 publication *Star-Names and Their Meanings* (Thank you again, Dover, for republishing this treasure!).

One might surmise that the rise of astrophysics and the general dullness of the arts in the present day, from architecture through poetry, would augur poorly for modern day uranographers, but such is not the case. *Sky and Telescope* alone boasts George Lovi and Walter Scott Houston as regular columnists, and Robert Burnham's three-volume set *Burnham's Celestial Handbook* (revised edition, Dover, 1978) is a monumental accomplishment which stands comparison with the best of the past.

In order to see more clearly the source of the uranographer's art, it may help to look at productions in an adjacent area: popular writings by great scientists. Representatives from this group come from the American astronomer (but Canadian born) Simon Newcomb (1835-1909) and the British trio of Arthur Eddington (1882-1944), James Jeans (1877-1946), and Fred Hoyle (b. 1915). Eddington's *The Nature of the Physical World*, for example, has brought me many hours of pleasure and edification. But the work flows from a more measured source than the lyric of the sky poet; we are reading Milton rather than Shelley. The spring of enthusiasm is the scientist's love of his professional field, translated to the common language.

However lovingly done, one's ear always seems to detect the act of translation in the popular works of the great scientists; the great uranographer, though a lesser authority, brings absolute freshness to his work.

An analogous contrast in styles is apparent in philosophy when one compares the writings of "amateurs" such as Marcus Aurelius (121-180) or Ralph Waldo Emerson (1803-1882) with a quintessential professional like Aristotle (384-322 B.C.).

Garrett Putnam Serviss was born on March 24, 1851 in Sharon Springs, New York. He graduated from Cornell University in 1872 with a bachelor's degree in science. The mixture of art and science was already evident since he had been Class poet in his sophomore year and belonged to the Adelphi Literary Society. The elevated stance which characterises Serviss' writings was presaged by the title of an oration he gave as part of Cornell's commencement ceremonies: "The Perpetuity of the Heroic Element."

The transition from science student at Cornell to author was an extended process which ran through law and journalism. A degree in law from Columbia University in 1874, with admission to the New York State bar the same year, was an experiment that went no further; Serviss never practiced law. However, his journalistic career was fruitful and introduced him to the writing of astronomy. Serviss started with the *New York Tribune* but, in 1876, joined the *New York Sun* where he achieved the first of his successes. He began writing anonymous articles on scientific, usually astronomical, subjects. These articles were placed adjacent to political topics and hence received broader attention than might have otherwise been the case. For a number of years the identity of "*The Sun's* Astronomer" was a matter of public speculation.

In 1882 he became night editor at *The Sun* and, during the ten years he served in this capacity, continued writing on astronomical topics and giving lectures on popular science in the New York area.

By 1892, his lectures were so suc-

cessful that Serviss resigned from *The Sun* to devote full time to expository work. The immediate cause of this change was an invitation by the industrialist and philanthropist Andrew Carnegie to conduct an extensive series of illustrated lectures.

Serviss' writings were based upon a personal acquaintance with the night sky going back to a boyhood on his father's farm. As an adult living in Brooklyn he employed a 3⅜-inch refractor at his home, not far from the eastern end of the Brooklyn Bridge, which had opened in 1883. As Joseph Ashbrook observed in his "Astronomical Scrapbook" article on Serviss (*Sky and Telescope*, January 1975), the Brooklyn skies were probably rather dark since the first electric lights were not installed in that borough until 1878.

Serviss was a prolific author with an immense number of newspaper articles to his credit. During the first two decades of this century he produced over a dozen books, with some novels of science fiction mixed into the series of astronomical works. A representative bibliography is contained in the memorial by his friend Clyde Fisher, of the American Museum of Natural History, in the August-September 1929 issue of *Popular Astronomy*.

Although Serviss always urged his readers to go out and look at the stars for themselves, he preferred language to graphics as a mode of exposition. His books are filled with colourful word portraits – "Vega or Alpha Lyrae, the astonishing brilliant that flashes on the strings of the heavenly lyre" – but the few charts and pictures are rather ordinary. In the preface to *Astronomy in a Nutshell* (1912), he made the doctrine explicit: "The author has been sparing in the use of diagrams...There is a tendency to try to represent everything to the eye...After all, it is only by an intelligent use of the imagination that progress can be made in such a science as astronomy."

Imagination was the hallmark of Garrett P. Serviss and constitutes the legacy left by this wonderful man. In 1894, he climbed to the top of the Matterhorn. Responding to his shocked friends he wrote: "Do you not know there are some things which are worth doing for their own sake?" How he would have thrilled to our modern voyages of exploration through the solar system!

Voyager at Neptune

Neptune is currently the most distant of the nine planets, exceeding even Pluto in solar range until early in the next century, and in this region of the solar system the Sun shines with little more than a tenth of a percent of its intensity at Earth. At 4:00 GMT on August 25, 1989, the Voyager spacecraft will fly approximately 29,200 km from the centre of Neptune; five hours and 14 minutes later it will pass about 40,000 km from the large satellite Triton. The scientific data gathered from the events surrounding this encounter will revolutionize our knowledge of the Neptunian system and complete the Voyager tour of the four gas giants: Jupiter, Saturn, Uranus and Neptune.

Garnering the harvest at Neptune is, of course, an endeavour that requires careful planning. Engineering preparations involve construction of observational sequences to be loaded into the spacecraft, upgrades to spacecraft and ground systems, and operational-readiness test and training. See the May 1988 edition of this column for the latest in a series of pieces on these topics (along with reference to previous pieces). This month we will examine some of the major scientific objectives and actions during the crucial near-encounter period, based upon a discussion with Dr. Ellis D. Miner, the Assistant Project Scientist for the Voyager Project.

Miner joined the project in June 1977, just prior to launch. After a few months as Experiment Representative for the Infrared Interferometer Spectrometer and Radiometer (IRIS: one of the four remote-sensing instruments aboard Voyager 2), he was appointed Assistant Project Scientist for the Saturn encounters of Voyagers 1 and 2 (Dr. Arthur L. Lane held a corresponding post for the two Jupiter encounters). Neptune will be his fourth encounter; number three, Uranus, took place in January 1986.

The structure of the encounter can be analysed hierarchically in terms of the concepts of "mission phase," "load," "link," and "command."

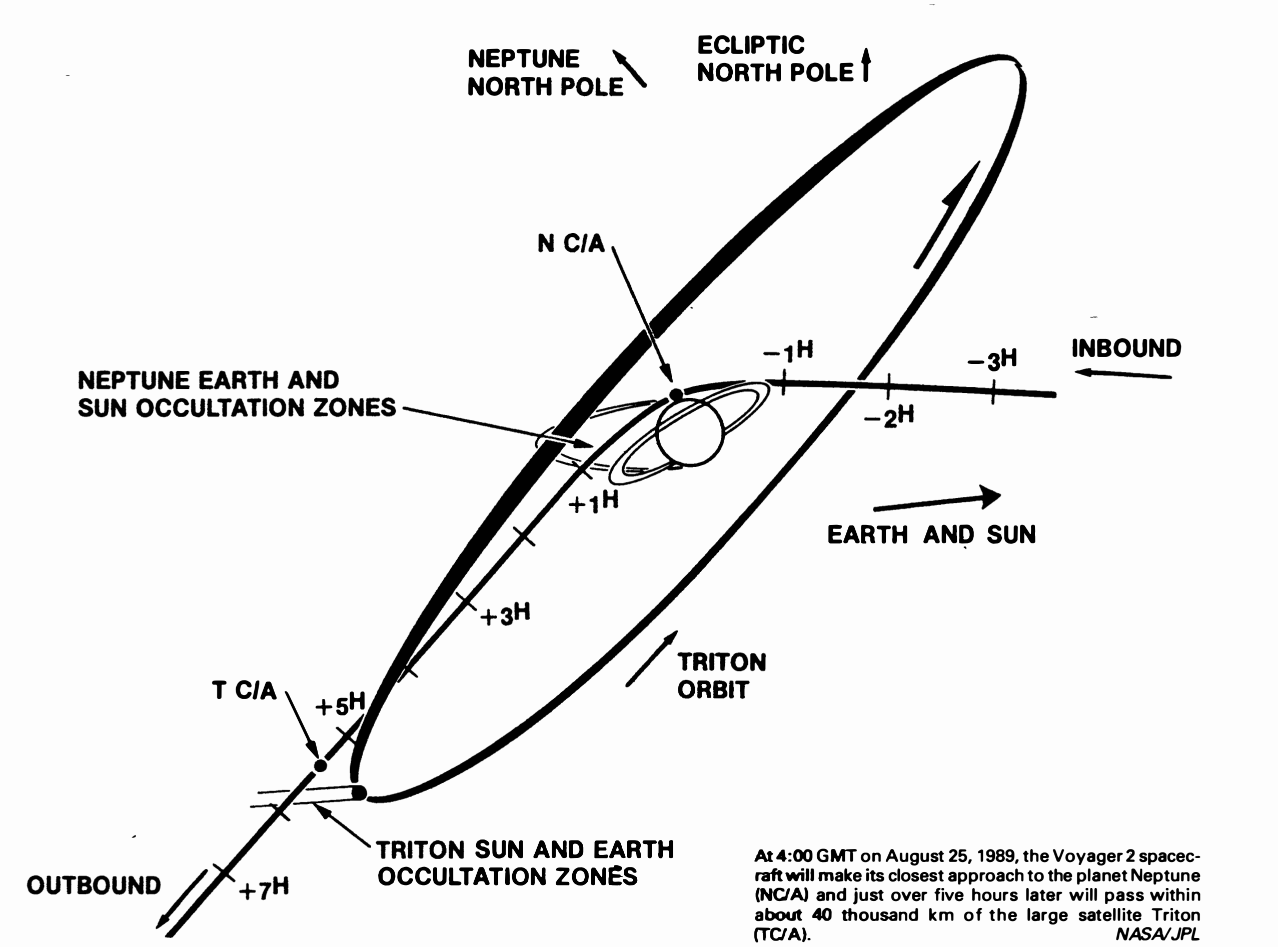
The approximate boundaries of the four mission phases, measured relative to closest approach to Neptune, are: observatory (-80d 21hr to -18d 19hr), far encounter (-18d 19hr to -00d 12hr), near encounter (-00d 12 hr to +04d 17hr), and post encounter (+04d 17hr to +38d 08hr). During observatory phase (starting June 4, 1989), instruments are calibrated and periodic observations of Neptunian atmospheric dynamics are undertaken. Activities in far encounter include capturing Neptune with mosaics built from the fields-of-view of remote-sensing instruments. High resolution observations, *in situ* fields-and-particles measurements, and the opportunity to probe Neptune's and Triton's atmospheres with electromagnetic waves are opportunities presented in the near-encounter phase. Post encounter provides a last look at Neptune from a perspective not achievable from Earth: behind the planet.

After Neptune, Voyager 2 will join Voyager 1 in post-planetary cruise, continuing to return valuable scientific data from the edges of interstellar space, perhaps into the first or second decade of the next century.

The two central computers of Voyager 2, the Computer Command Subsystem (CCS), determine the next level of the encounter hierarchy: loads. Each CCS computer has a memory capacity of 1239 18-bit words available to receive the load of the sequence of commands for guiding the spacecraft's program of activities for a specified period of time. Approximately 150 of these 2478 words are devoted to providing protection in the form of a minimal encounter program should Voyager 2's connection to Earth be broken by failure of its one remaining receiver (the primary receiver failed in 1978). During the heart of the encounter, these 150 words of memory are converted to direct use in the observing programme.

The period of time that it takes the spacecraft to use up a load is variable (a load is sometimes referred to as a "sequence;"the activity of building a sequence is, quite naturally, called "sequencing," and your correspondent is Manager of the Mission Profile and Sequencing Section at JPL). Naturally, activity is more intense during the near-encounter phase than any other. Thus, the two sequences (totalling almost 5000 words) which comprise the near-encounter phase are eaten up in little more than five days, while almost three weeks are required to consume each of the two loads which span the post-encounter phase (the observatory and far-encounter phases are each composed of three sequences).

Dropping down one more level in hierarchy, the "link" is reached (mission phase, load/sequence, link). "Link" is a conceptual unit employed in science planning and labels a specific activity. For example, the planned observation of Neptune's rings when the spacecraft is behind the planet and the rings are flooded with sunlight from their rear, as seen from Voyager 2, is accomplished by a link. Each link is described by means of a trinomial name: "ABC^n" "A" encodes the identity of the leading spacecraft instrument in the activity; "B" identifies the observational target; and "C^n" furnishes a brief description of the activity. The link mentioned above is "VRHIPHAS" (A=V, B=R, C^6=HIPHAS). The letter "V" (visual) denotes the use of the camera for the observation, "R" refers to the Neptunian rings as the target of the observation, and "HIPHAS" encapsulates the fact that the observation takes place at a high phase angle (the "phase angle" portrays the illumination condition of an



At 4:00 GMT on August 25, 1989, the Voyager 2 spacecraft will make its closest approach to the planet Neptune (NC/A) and just over five hours later will pass within about 40 thousand km of the large satellite Triton (TC/A). *NASA/JPL*

object and, here, equals the Sun-rings-camera angle).

The final level of the hierarchy is populated by the commands which are issued from the CCS computers, each command consisting of a few words (words constitute an even lower level, if you wish). An example of the result of a command is turning on the spacecraft's camera.

Miner characterises the process of synthesising the complex near-encounter sequences as a team effort which involves many individuals. Four science working groups – atmospheres, rings, satellites, and magnetosphere – submitted their reports on scientific objectives and preliminary sequence designs on July 15, 1987. Selected highlights of this report, and subsequent development, will be reviewed with respect to the near-encounter phase. Given the scientific objectives, the trick is to string the links together in a way that satisfies these objectives while staying within the envelope of shared resources: CCS words, power, data rates, ground-station coverage, tape-recorder storage, spacecraft orientation, pointing of the scan platform (on which are located the four remote-sensing experiments of Voyager's complement of eleven experiments), etc.

Let us now look at the four scientific disciplines which were addressed by the working groups.

Neptune, like the other three gas giants, is eternally wrapped in clouds. Triton is one of the two satellites in the solar system which possesses a significant atmosphere (Titan, Saturn's largest satellite, is the other). The study of the atmospheres of Neptune and Triton constitutes an important element of the encounter and is a multidisciplinary activity. The Neptune atmospheric-science working group identified several scientific objectives including global energy budget, vertical and horizontal structures, determination of composition, and identification of possible auroral phenomena at both poles. Thirty links were formulated for the purpose of addressing these objectives.

The global energy budget of Neptune (or Triton) consists of three primary terms: the incident solar energy, the reflected solar energy, and the energy derived from the interior of the planet. Miner said that understanding the energy budget of the planet conveys important information about the state and origin of that body. Voyager measurements at Jupiter and Saturn revealed these planets generate in their interiors about one and three quarters the amount of energy they receive from the Sun. In the case of Jupiter, this excess energy may arise from the primordial heat associated with the formation of the planet, while the Saturnian excess has been ascribed to frictional heating from the gravitional sinking of helium in the atmosphere. Little or no excess was observed by Voyager 2 at Uranus.

A key measurement in establishing the global energy budget of Neptune is provided by the link RPDISK, which employs the above-mentioned IRIS instrument (the "R" in the link name denotes this instrument; the "P" indicates that the planet is the object of observation). The "DISK" descriptor points to an essential aspect of the link – picking the correct points on the trajectory, before and after closest approach, where the apparent diameter of the disk of Neptune almost exactly matches the size of the field-of-view of the IRIS. This coincidence takes place about one week before encounter and again one week after encounter.

With the emitted thermal radiation measured by IRIS accounting for one term in the global energy budget, it remains to determine the amount of incident solar energy scattered by the atmosphere. The third term, solar radiation incident on the planet, is easily calculated from astronomical factors and does not require measurement by

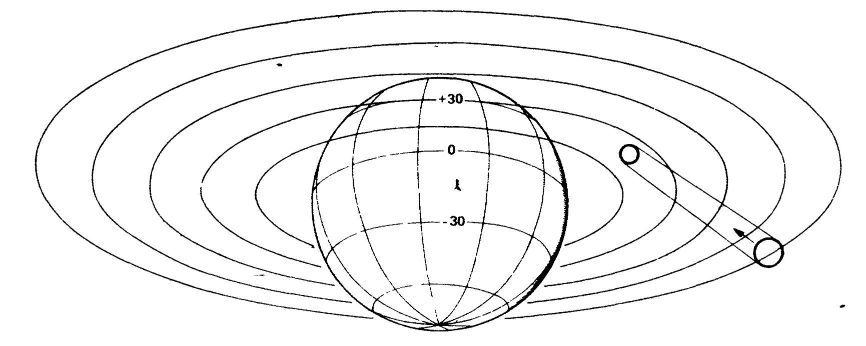
Voyager. The scattered radiation is a function of the phase angle, as defined above, and is determined by means of photometry using the wide-angle camera, the IRIS, and the photopolarimeter (the third of the four remote sensing instruments; the fourth is the ultraviolet spectrometer or UVS).

The RTDISK link applies IRIS to Triton, hence the "T", and, according to Miner, will reveal more about the degree of consolidation of the surface of this satellite than about interior processes. He illustrated the situation with the Earthly examples of beach sand (unconsolidated material) and concrete (consolidated). The former appears hot when illuminated and cold when in the dark. The latter is less extreme in its thermal behaviour under solar input.

The physical structure of an atmosphere is revealed through its vertical and horizontal features. Several links contribute to the analysis.

The horizontal structure and meteorology of Jupiter's atmosphere provided a stunning spectacle when Voyagers 1 and 2 visited that planet in 1979. Saturn's atmosphere was more subdued, and the glorious system of rings furnished the visual jewel of the 1980 and 1981 flybys. The Uranian atmosphere was quite bland; the bizarre topography of the satellite Miranda and the skewed planetary magnetic field yielded the principal surprises of the encounter.

Earth-based observations give some reason to believe that the Neptunian atmosphere may yield more visible structure than was the case at Uranus. The human eye will collaborate with Voyager's narrow-angle (NA) camera in link VPNAMOVI which strings together, into a movie, planetary images taken every 72 degrees of longitude. Assuming a planetary rotational period of 17 hr 52 m, images taken at intervals of 3 hr 34.4 m will yield the desired frames for the movie,



A few hours before its closest approach to Neptune, Voyager 2 will observe with its photopolarimeter the passage of the star Sigma Sagittarii as it passes behind a portion of the suspected system of planetary rings. *NASA/JPL*

which is to be made from -5 d 6 hr to -2 d.

Determination of wind speeds in the atmosphere depends upon observation of cloud speeds and a knowledge of the internal rotation rate of the planet. After the latter quantity has been measured using data from the Planetary Radio Astronomy (PRA) experiment (the two 10m whip antennas of the PRA detect radio emissions indicative of the planet's magnetic field and allow a determination of the rotation rate of that field = the planetary rotation rate), a simple vector calculation yields the wind speed: motion of the clouds relative to the planet.

The vertical structure of Neptune's atmosphere will be investigated by a variety of techniques.

Direct imaging of possible aerosol layers will be attempted with the camera in link VPHAZE. The link will be executed at a high phase angle since small particles – dust in atmosphere, dust in planetary rings, or dust sticking to the windscreen of your automobile – show up best in "forward scattering" (particles significantly larger than the wavelength of light being scattered show up best in "backward scattering"; as an extreme example of backward scattering consider the full Moon versus the new Moon).

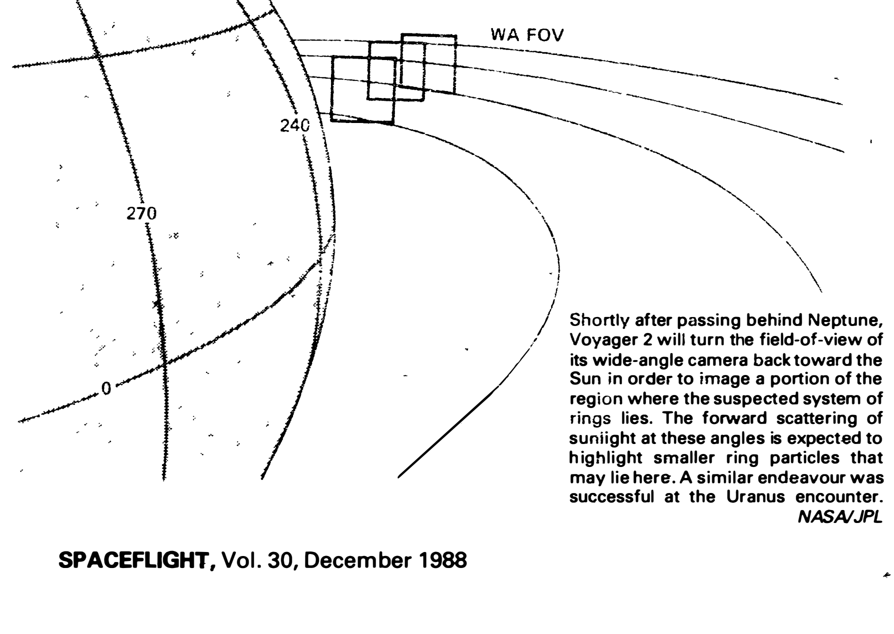
Link XPOCC ("X" for the spacecraft's radio system, "P" for planet, and "OCC" for occultation) is accomplished by passing radio waves through the atmosphere of Neptune, when the spacecraft is behind (occulted by) the planet. Upon receipt at Earth, analysis (in combination with earlier IRIS data) will reveal secrets of the structure, temperature, pressure, and bulk composition of the atmosphere. This link is of very high priority for the encounter and must be carefully executed. The design calls for 24 chords of Neptune's disk to be traced by the precisely pointed antenna of Voyager 2 as it radiates radio waves at two frequencies (X-band and S-band). The link will require about 50 minutes for execution and will be redesigned at practically the last minute in order to take advantage of the latest navigational information.

A shorter duration (four minute) link, XTOCC, will probe Triton's atmosphere. But it is felt that this thinner atmosphere will be more fruitfully analysed by observing the diminuation of sunlight by the atmosphere, as seen by the UVS onboard Voyager 2: link UTHOCC (the "H" stands for "helios", signifying a solar occulation). A similar experiment, UPHOCC, done earlier, will contribute to Neptunian atmospheric studies.

Not only radio waves and sunlight but also starlight provide information on structure and composition when traversing the atmosphere. The star Beta Canis Majoris will be watched, by the photopolarimeter and UVS in links PTBETCMA and UTBETCMA, as it drifts through Triton's atmosphere.

Finally, in atmospheric science, the close passage of the spacecraft over Neptune's north pole will facilitate auroral studies by several instruments.

Interest is high with regard to Neptunian rings, but Miner issued the reminder that it is not even certain that these objects exist. Unlike Uranus, nine of whose thin rings were rather well mapped before the encounter, stellar occultations by the Neptunian system, observed from Earth, have given mixed signals. One possibility is that only partial rings, ring arcs, are present. If such arcs spanned about 10 per cent of a ring orbit, leaving 90 per cent empty, the observations from Earth might be explained. One



Shortly after passing behind Neptune, Voyager 2 will turn the field-of-view of its wide-angle camera back toward the Sun in order to image a portion of the region where the suspected system of rings lies. The forward scattering of sunlight at these angles is expected to highlight smaller ring particles that may lie here. A similar endeavour was successful at the Uranus encounter. *NASA/JPL*

hypothesis suggests that the rings could even be polar, rather than equatorial, and Voyager 2 will check for such an entity.

About 18 links have been devised for ring studies. VRHIPHAS has already been mentioned. In addition, URHOCC will look at the Sun through the rings with the UVS, and URSIGSGR and PRSIGSGR will utilise the UVS and the photopolarimeter to observe a star, whose name the reader can readily infer, as it is occulted by the rings. And, of course, considerable synoptic and high-resolution system observations by the imaging system are planned. Radio science has not been neglected: witness link XROCC.

There are only two known satellites of Neptune: Triton and Nereid. Triton is in a nearly circular orbit at 355 thousand km from the planet but traces this orbit in a tilted retrograde direction. The diameter of this large satellite is very poorly known; it could be as large as 5000 km or as small as 2200 km (Earth's satellite lies in the middle of this size range). The uncertainty in size complicates observational planning with regard to remote sensing and makes it very difficult to carry out the kinds of occultation experiments discussed above. Nereid is a much smaller object and will not be closely observed by Voyager 2. If its diameter is 800 km, at the closest approach of 4.7 million km the satellite's disk will only span eighteen picture elements (pixels) in the focal plane of the narrow-angle camera (the focal plane is made up of 800 x 800 pixels).

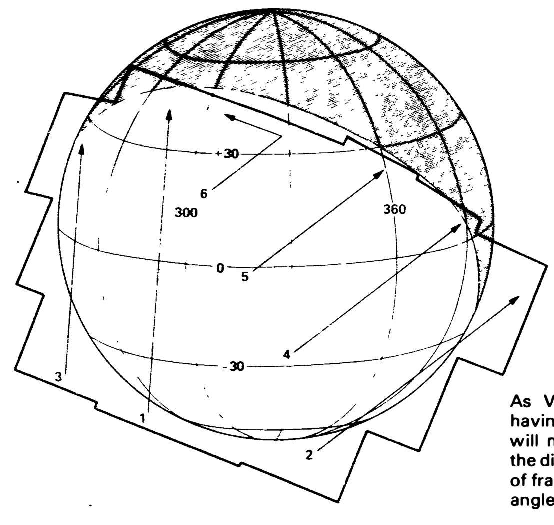
In addition to Triton and Nereid, there are almost certainly smaller, undetected satellites which will be discovered by Voyager 2. At Uranus, 10 such objects were found, and a link, VSATSRCH, has been designed to look systematically for new objects interior to the orbit of Triton.

Approximately 30 links have been prescribed for the study of Triton and Nereid; the emphasis on Triton is evident from the fact that only three of the links focus on Nereid.

The diameter and shape of Triton will be well determined through imaging, and its mass (and that of Neptune) will be derived from radio tracking of the spacecraft's motion. Imaging taken near the closest-approach distance of 40 thousand km is expected to resolve features as small as 1 km, comparable to the resolution Voyager obtained for the Uranian satellite Miranda.

Lighting conditions along a terminator are always favourable for imaging due to sharply etched contrasts. The link VTERM will lay down a mosaic near the terminator at a resolution of about 4 km. (Note the notational economy, "VTTERM" could have been used, artificial terminologies seem to follow some of the rules of development that natural languages obey).

The exploration of the solar system has revealed the importance and diversity of magnetospheres – those electromagnetic cocoons, filled with charged particles and plasmas, that enwrap planets. The "bowshock" of the magnetosphere is formed in the region where the flux of particles from the Sun, the solar wind, slams into the magnetic field of the planet. The magetosphere extends asymmetrically behind the planet in the form of a "magnetotail".



As Voyager 2 approaches Triton, having already passed Neptune, it will map the illuminated portion of the disk of that satellite with a mosaic of frames laid down with its narrow-angle camera. *NASA/JPL*

Although it is not certain that Neptune even has a magnetosphere, it would be a surprising fact if it did not, and extensive planning is being done to collect the anticipated data.

Assuming the presence of a magnetosphere, there are several scientific objectives for its study during the flyby: accurate measurement of the magnetic field, characterisation of the plasma in the system, determination of the internal rotation rate of Neptune, and investigation of the physics of the magnetosphere (energy sources, plasma sources, plasma sinks, wave-particle interactions, radio-emission mechanisms, etc.). Over 30 links will be dedicated to the program of observations which will address these objectives.

The magnetometer experiment employs two low-field magnetometers removed from spacecraft interference by locations at the far end of a 13m-boom and at 7.4m out on the same boom; the two magnetometers which measure high-level fields are not so sensitive and are located inboard. It is crucial for the construction of a magnetic-field model to be able to measure accurately the orientation of the spacecraft, especially during the passage through the heart of the magnetosphere (plus and minus two hours about closest approach to Neptune). Hence, spacecraft manoeuvres, which always introduce uncertainties, will be avoided to the extent possible during this period of time.

Plasmas are collections of electrically charged particles (ions) whose total charge sums to zero, considering the material *en masse*. They are prevalent throughout the Universe, existing at high and low temperatures, and have sometimes been described as the fourth state of matter (in addition to solid, liquid, gas). An important plasma experiment is to measure cold plasma which may be co-rotating with the planet. To accomplish this, the instrument for the Plasma Science (PLS) experiment must be aligned so that the side-looking collection cup points into the flow of plasma.

The pointing of the PLS, which is not an articulated instrument, must be done be selecting an appropriate lock star for the spacecraft's star sensor (Voyager 2 orients itself with a Sun sensor and a star sensor, going occasionally upon an internal reference system provided by gyros). The "roll strategy" to implement the PLS pointing scheme involved utilising Canopus as the stellar reference for inbound measurements, then at 56m before closest approach rolling to a suitable inertial-reference position, and, finally, performing a second spacecraft manoeuvre to roll to the star Alkaid at 1 hr 50 m after closest approach. Both roll turns conflict with the above-mentioned desire to minimise spacecraft manoeuvres for the sake of the magnetometer experiment and illustrate the necessity of the tradeoffs which permeate the design of the whole encounter.

From the present pre-encounter perspective one might expect ring structures or some startling aspect of Triton (reflective lakes of liquid nitrogen?) to provide the centerpiece of the encounter. But each Voyager planetary encounter has served up surprises: volcanos on the Jovian satellite Io, endless nests of rings at Saturn, a patchwork quilt of a satellite at Uranus. Whatever turns out to be the case at Neptune, the big winner will be our increase in knowledge from the last planetary encounter of one of NASA's most productive scientific facilities.